Understanding demand for wood products in New Zealand's major log markets

A dissertation submitted in partial fulfilment of the requirements for the degree of Bachelor of Forestry Science

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2015

Abstract

New Zealand's forestry sector is largely reliant on the presence of a strong export market with 57% of the volume harvested being exported of which 99% goes to Japan, the Republic of Korea, China and India. This identifies the need to analyse demand in these countries to better understand their needs in the future. Consumption of wood products per capita is a commonly used metric for estimating demand and was used in this research. Volumes of imports, exports and production were collected from the Food and Agricultural Organisation of the United Nations (FAO) and data for a range of explanatory variables was collected from a variety of official sources. Historical trends in consumption identified that as countries develop socially and economically their consumption shifts from largely solid wood products such as sawn timber to more processed products such as wood-based panels and paper and paperboard. Consumption was modelled using linear regression techniques to develop models which could be used to forecast consumption in the future. A wide variety of potential explanatory variables were considered and the models presented represent the most effective of these. GDP per capita was found to be the single most effective explanatory variable being highly significant ($p<0.01$) in all models. Price was also found to be a strong determinant of consumption, understandable as price is a major component of supply and demand dynamics. Measures of construction activity were found to be related to consumption of sawn timber in all studied countries and for wood-based panels in Japan. Forecasts produced for consumption in Japan should be used as only an example of the capability of the models presented herein. More work is required to develop these equations into a form where they can be used to more accurately estimate future consumption.

Keywords – demand, wood products, consumption, per capita GDP, linear regression, sawn timber, paper and paperboard, wood-based panels.

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Acknowledgements

I would first and foremost like to thank Dr David Evison for his supervision, guidance and help which he has kindly offered me throughout the duration of the research. Furthermore, I would like to thank Dr Richard Woolons for his sharing his expertise in modelling complex statistical relationships.

Finally I would like to thank my parents Grant and Fiona for their support and input during the research and the rest of my fourth year class who provided an effective sounding board and much entertainment throughout our final year.

1. Introduction

Forestry is New Zealand's third largest industry by value and relies heavily on the presence of an export market. The export market is based strongly on exports of logs with 57% of the annual harvest exported in 2014 (MPI, 2015). The export market exists primarily in the Pacific Rim and the success of these markets determines the profitability of forestry investment in New Zealand. It is therefore important to understand these markets and predict their demand for wood products.

Approximately two thirds of forest product exports go to China, Japan, the Republic of Korea, and India (MPI, 2015). As these countries have developed over time their consumption of wood products has changed considerably in some cases. Not only has their total consumption changed but so too has the composition of their consumption. New Zealand has seen demand for logs in China increase rapidly over the past twenty-odd years moving from eleventh most important to first in only ten years as an export destination for forest products in terms of value. Comparatively Japan has lessened its importance over time as their economy has developed and their demand has changed (FAO, 2015).

Work has been carried out in the past in an attempt to predict future consumption of wood products at varying scales and with varied success. The nature of predicting future trends in consumption makes estimating demand more art than science with such a vast array of variables influencing how markets behave. What's more, valuable predictors for one market may not be suitable for another as different markets respond differently depending on historic use patterns and preferences. In addition, little work has been done in the past focusing on making predictions between countries, assuming that countries follow similar consumption patterns.

There is therefore an interest from exporters, manufacturers and forest growers to investigate the future of their most important export markets currently. Being able to predict future consumption in these large markets has the potential to aid these groups in making investment and marketing decisions.

This dissertation addresses the current and historical consumption of wood products in New Zealand's four major markets for logs. This is quantified in a roundwood equivalent

(RWE) form to determine the total demand for fibre. A selection of literature was reviewed in order to place this research in context with the work of others and also to obtain a greater understanding of the problem. The research attempts to relate changes in consumption to economic and demographic development through analysis of relationships between explanatory variables and consumption. Part of the analysis involves looking at how the consumption has changed over time as a result of these drivers of demand. Finally it presents a series of models developed to predict changes in consumption using predictor variables and forecast consumption into the future.

2. Problem statement and objectives

New Zealand's high reliance on the export markets for the continued prosperity of the forestry industry means that it is important to understand the future directions for the country's largest markets. Much of the opinion on the direction of our major markets is speculative, however little has been done to attempt to truly quantify the future needs of these markets.

Predicting the consumption of wood products is inherently difficult because of the broad range of factors which have the potential to influence future consumption. Previous studies have encountered these challenges and as a result their estimates have been less than accurate.

This study has the opportunity to increase the knowledge industry has relating to factors influencing demand for wood products by developing relationships between drivers and demand. It also has the potential to aid marketing and investment decisions. It hopes to assess what stimulates demand for raw and processed products, and what drives the progression from one to the other.

2.1. Research questions

- For New Zealand's major log markets, what are the total material flows in roundwood equivalent terms, and how do these relate to indicators of economic activity and development?
- What are the main drivers of demand for wood products in these markets?

- How has the composition of demand for forestry products changed and what drives progression towards processed products in these markets?
- What is the consumption of these wood products likely to be in the future?

3. Literature review

In order to gain a greater understanding of the subject area and work completed in the past, a subset of literature relevant to the study area has been selected for review. This review will outline the methodology, assumptions and analysis which this research intends to utilise. In addition the review will look at the strengths and weaknesses of this previous research to ensure that this study provides high quality results and projections.

3.1. Estimating demand

Apparent consumption of wood products is often used as a predictor for the demand for wood products. In order to make consumption comparable between countries it is commonly expressed as apparent consumption per capita. Apparent consumption is used as opposed to consumption as consumption itself, which is the amount of a product actually used, is difficult to measure, therefore apparent consumption is calculated as a function of imports, exports, and production (Buongiorno, 1977; Buongiorno & Grosenick, 1977; Gregory, 1966; Kayo, Oka, Hashimoto, Mizukami, & Takagi, 2015; Zhang, Buongiorno, & Zhang, 1997).

3.2. Roundwood equivalent calculation

There is little evidence in past literature of attempts to estimate demand in roundwood equivalent volumes. The value of calculating consumption this form is it gives an estimate of the total production of roundwood required to service demand at the product level and makes it easily comparable to the annual harvest volumes. Literature in the past has focused on predicting the demand for quantities of product which is, in a sense unhelpful for forest managers. Product quantity estimates require conversion of these quantities to roundwood equivalent before the grower has any indication of the potential demand for their forest outturn.

3.3. Predictor selection

3.3.1. Economic predictors

Literature has focused strongly on the use of income per capita as a predictor of wood product consumption (Buongiorno, 1977; Buongiorno & Grosenick, 1977; Gregory, 1966; Kayo et al., 2015; Simangunsong & Buongiorno, 2001; Zhang et al., 1997). Income is closely linked to consumption of wood products as with increasing wealth of a population, people are more willing to purchase wood products. Gregory (1966) theorised that in very low income areas where spending on necessities such as food and clothing was the priority, wood consumption was less sensitive to income. Once these basic needs are met then income was expected to have a greater correlation with consumption as industrial and building activities increase. Gregory (1966) also stated that beyond some point wood consumption may begin to decline as income exceeds some level as income would instead be used for purchasing services or non-wood items. This agrees with the relationship proposed by Kayo et al. (2015) which suggested that an environmental Kuznets curve (an inverted U-shaped curve) existed between per capita income and per capita consumption of wood products. By contrast, Whiteman and Brown (2000) suggested that timber demand followed a U-shaped curve. They suggested that as income increases poor communities would move away from timber use toward cement and bricks, and wealthier urban families would use more wood flooring and furniture as their income increases. This progression could be in part be due to cultural preferences where in North American and Germanic cultures wood is a favoured building material while in Spanish cultures the material is not preferred.

3.3.2. Non-economic predictors

Past literature has also identified that some product categories are less influenced by changes in national income and more by other factors related to economic development or resource availability. Wood availability was identified by Gregory (1966) as being a significant ($p<0.05$) factor influencing wood product consumption. Wood availability was defined as a function of the area of managed forest divided by the total population in a country. The wood availability in a country influences the fibre supply dynamics by influencing the volume of fibre required by imports to satisfy demand. This gives an indication of the supply dynamics in the country. Kayo et al. (2015) used the proportion of total land area in forest as an estimation of domestic fibre supply and found that it had a significant ($p<0.05$) relationship with per capita consumption. This metric fails to consider the productivity of the forest, or that much of this forest may not be under any kind of management or harvesting plan. This is the case in China where 90 million hectares is entirely excluding from harvesting activities under the National Forest Protection Program (NFPP) (Whiteman & Brown, 2000; Yin, Xu, Li, & Liu, 2003). Furthermore, the international trade in wood products has resulted in domestic wood supply being less important in regards to a country's consumption as they have the option to import wood fibre from other countries relatively easily.

In literature, there is speculation as to the validity of using a rural/urban ratio to explain wood consumption. The concern is that due to this variable's high correlation with per capita income that its inclusion is unnecessary as it leads to multicollinearity (Gregory, 1966). Kayo et al. (2015) found that urbanisation, the same metric with a different title, had a significant ($p<0.05$) negative correlation with wood-based panel and sawn timber consumption, and suggested that value was added to the model by including the predictor. Similarly, they used population density as a predictor which was found to have a significant ($p<0.05$) negative influence on the consumption of these same products. This is potentially explained by substitution of wood with high strength components such as cement and steel for use in high-rise buildings (Kayo et al., 2015).

The Human Development Index (HDI) was used by Kayo et al. (2015) as a predictor for wood consumption and measures the expected quality of life in a population. The HDI is an index encompassing life expectancy, adult literacy rate and education enrolment ratio, and GDP per capita. Kayo found that the HDI had a significant relationship ($p<0.05$) with the consumption of wood products in the 39 countries which were assessed. Here again, the value of including the HDI is questionable as the HDI is highly correlated with GDP per capita. Furthermore the two additional indices used to calculate the HDI, literacy and education rates and life expectancy, cannot logically be expected to directly influence the consumption of wood products which would potentially indicate that the relationship identified existed solely with GDP per capita. Inclusion of the HDI would lead to multicollinearity and may actually cause the adjusted coefficient of determination to decrease.

3.4. Assuming countries are comparable

A key assumption made in previous research and intended for use in this study is countries are entirely comparable in terms of their wood product consumption. It assumes that a country moving from a lower income or development level to higher level will take on the characteristics of the country presently at that higher level. Gregory (1966) correctly stated, "This at best, is a highly questionable assumption," he noted that there are clear differences in the ways in which countries operate. Zhang et al. (1997) also made this assumption when they used Korea as a predictor country for estimating future wood consumption in China. The equation which they developed assumed that when China's income per capita was equal to Korea's they would have an equivalent consumption. They justified their selection of Korea noting it was similar to China in economic growth rate and the limited supply of domestic wood fibre. Buongiorno (1977) described the potential inaccuracies that this could cause, identifying that a country with an aggressive housing policy would have an above average consumption of sawn timber. Conversely another country with a weak housing policy would have below average consumption of sawn timber. The two countries would react differently to a given change in income with the country with lower initial consumption increasing more than the other (Buongiorno, 1977).

Similar to the justification offered by Zhang et al. (1997), this study will assume that the four countries studied are similar enough to be comparable to one another. If this assumption were considered valid it would help with forecasting future consumption especially in cases where a country has a range of markets for the same product, all at different stages of development (as for New Zealand's four log markets). Korea and China have previously identified as being similar enough for comparison, with fast growth rates and limited forest resources (Zhang et al., 1997). The argument here is India is in the same situation, possibly just beginning to rapidly grow and having a limited forest resource. The same is true for Japan which in the past had a fast growth rate and while they did not have a limited forest resource, they had limited fibre supply as these resources existed in protected reserves (The World Bank, 2015).

3.5. Future consumption estimation

Before making decisions surrounding predictor selection or regression methodology based on the literature, it is important to assess the success of the researchers based on their proposed models. The variation between the predictions offered and the actual consumption could be a result of the effectiveness of the proposed model or the future estimates for predictors such as GDP, population, price etc.

A list of the projections made by others and their accuracy is presented in Appendix 1. The major assumption in most of these studies was in estimating GDP per capita across the projection period hence the values assumed are presented and compared with the observed growth rate. The data on actual apparent consumption was collected from FAO (2015) allowing a comparison between estimates and actual consumption to be drawn.

Zhang et al. (1997) suggested values for consumption from 1993 to 2010 for paper and paperboard, and wood-based panels under both a high and a low economic growth rates, 9% and 6% respectively. The actual annual GDP growth rate across the period was on average 10.6%. The analysis estimated that in 2010 consumption of paper and paper board would be 81.7 million m^3 and 106.9 million m^3 under the low and high growth rates respectively. This was near to the 96.8 million actually observed in 2010. For wood-based panels their model severely under predicted consumption, possibly in part due to a lower assumed growth rate, projecting consumption of 26.6 million m^3 and 34.8 million m^3 under the low and high growth scenarios respectively compared to 95.9 million m^3 actually consumed in 2010. A sawn timber consumption estimate was calculated under a low growth rate exclusively and again severely under predicted consumption. Zhang et al. estimated 14.1 million m^3 of sawn timber would be consumed in 2010 when statistics show consumption was 52.6 million m^3 (FAO, 2015; Zhang et al., 1997).

Buongiorno and Grosenick (1977) developed two models to predict demand in developing and developed countries, with world demand being estimated as the sum of these two predictions. They estimated consumption each decade from 1970 to 2010 inclusive. World GDP growth was estimated to be 3.4% annually, when in reality it was 7.7%. This significant under prediction of GDP growth was likely due to the unforeseen acceleration of the Chinese market which was fairly modest until the economic reform of 1978 (Jaggi, Rundle, Rosen, & Takahashi, 1996; Zhang et al., 1997). As a result of this inaccuracy, the estimates produced greatly over predicted industrial roundwood, sawn timber, and paper and paperboard consumption. Prediction ranged between 170-420% higher than actual values observed in 2010 (FAO, 2015).

D. He and Barr (2004) made predictions for China's consumption based on models developed by China Economic Consulting Incorporated in the period 2003 to 2010 inclusive. The model used is confidential hence the omission of a figure for assumed GDP growth rate in Appendix 1. Baseline estimates and also upper and lower confidence intervals were provided for each product category, the baseline estimates are also included in Appendix 1. He and Barr's projection of paper and paperboard consumption under predicted; estimating 68.5 million m^3 while consumption was observed to be 96.8 million m^3. Conversely, for wood pulp the model severely over-predicted estimating consumption at 59.6 million m^3, when only 19.6 million m^3 was consumed in 2010 (FAO, 2015). Without knowing how the model was formulated it is difficult to attribute this discrepancy to any factor.

The most successful forecasts from the literature reviewed was based on the analysis of Whiteman and Brown (2000), which used the Global Fibre Supply Model (GFSM) and the Global Forest Product Model (GFPM). The GFSM uses information including forest area, type and stocking, logged area, and information relating to barriers to resource use such as political, biological or topographical. The GFPM uses production and trade data for forest products to estimate future production based on capacity and align this with future demand for these products across many countries. The key difference between the two is the GFSM is based on the growth of forests while the GFPM is based on the product markets and trade. The nature of these models does not require the estimation of GDP growth rate hence its omission from Appendix 1. While the projection period is relatively short, 2000-2010, results appear much more accurate than alternative methods. The projections for all product categories except wood-based panels were relatively accurate. The estimate for world consumption of wood-based panels in 2010 was 180 million m^3 when observed consumption was almost than double this at 355.7 million m^3. Estimates for the other categories were not more than 35% from the true consumption figure (FAO, 2015).

4. Methods and materials

4.1. Data

Included in the analysis were New Zealand's four current largest log export markets the People's Republic of China, Japan, Republic of Korea and India. It was proposed that India was least developed followed by China, South Korea and finally Japan, being the most developed.

All wood products were included in the analysis with the exception of wood fuel. These products are aggregated under the FAO system into five broad categories under industrial roundwood, sawn timber, wood pulp, wood-based panels, and paper and paperboard headings. In total 26 wood product categories were analysed under these aggregates.

The analysis used data between 1961 and 2013 (53 years) to develop relationships between explanatory variables and apparent consumption. This period was chosen as trade data for all countries was available as far back as 1961 from FAO (FAO, 2015).

Data for predictor variables was collected from a range of official sources, to ensure the greatest possible integrity of the data. A list of data sources can be found in Appendix 2.

In order to model future trends an indication of the expected value of the predictor variables was required. For example, a model which uses real GDP per capita as a predictor would require estimated future values for this variable in order to forecast future consumption. For some variables this meant obtaining data from official forecasting sources and for others it meant making justifiable assumptions as to future values.

4.2. Methods

The quantity of imports, exports and production data were collected from the FAO database for Japan, South Korea, China and India. These were then converted into roundwood equivalent volumes using a series of conversion factors published by the United Nations Economic Commission for Europe (UNECE) (FAO, 2010a). Each individual category had a unique conversion factor which was applied. Quantities were converted to roundwood equivalent volumes so the total fibre requirement could be determined. A table of the conversion factors used is presented in Appendix 3.

Fuelwood was excluded from all calculations of consumption as it is not a commonly traded product. Fuelwood consumption is essentially exclusively supplied by domestic consumption making it unimportant when it comes to determining the demand for wood products from other countries (FAO, 2015). Fuelwood is not a commonly traded product as the cost of shipping such a product is often greater than the value of the material itself, making the cost of purchasing imported fuelwood prohibitive.

To calculate the apparent consumption of wood products in roundwood equivalent volumes, exports were subtracted from the sum of production and imports. This total annual apparent consumption was divided by population to produce annual apparent consumption per capita in roundwood equivalent terms. From this point forward apparent consumption will be referred to as simply 'consumption'.

There was extensive preparation of data including calculation of per capita metrics for the explanatory variables. Value and price data was converted from nominal to real terms using either a producer price index (PPI) or consumer price index (CPI) as appropriate to assess actual changes in values.

Exploratory data analysis was used to establish relationships between the response variable, consumption per capita, and a range of potential explanatory variables. This involved graphical analysis as well as building linear regression models which could assess the strength of relationships and provide information on the likely predictive capabilities of the models.

Following the determination of a series of suitable predictors for a range of products and countries, models were formed which have the ability to estimate potential consumption in the future. Non-linear regression was also used to model some of the more complex relationships uncovered by the exploratory data analysis.

Price was used as an explanatory variable for a number of models however there is little forecasting information available to base consumption forecasts on. As a result it was necessary to develop a strategy of predicting price. These strategies included an assumption that price either remained constant in real terms or that prices followed a linear change equivalent to the past 53 years.

5. Results

5.1. Historical apparent consumption

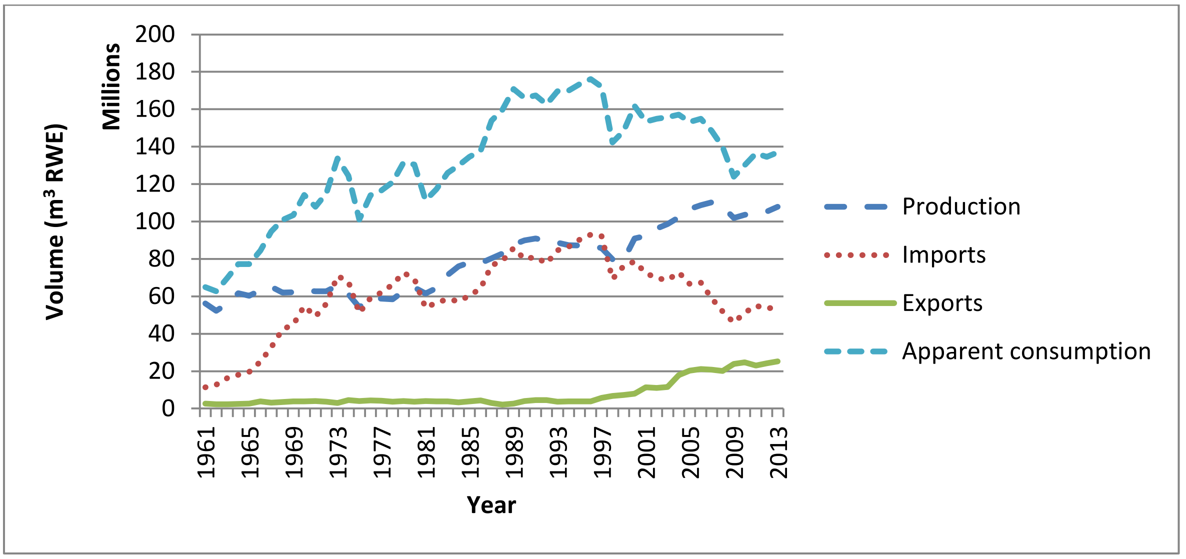

Figure 5.1. Production, imports, exports and consumption of wood products in Japan over time.

Japan's consumption of wood products grew until the mid-1990s after which point there has been an average decrease of 1% annually since 1996. This decrease was due to both decreases in imports of wood products and an increase exports. Domestic production has increased over time, a result of increased production of paper and paperboard products which have a high conversion factor (average 3.6 m^3 log input per m^3 product output) resulting in an increase in the roundwood equivalent consumption (FAO, 2010b). The increase in exports has been driven almost exclusively by the wood pulp industry and, to a lesser extent, the pulp and paper industry which is fed largely by the domestic wood pulp production in the country. Japanese wood consumption has been affected by global economic factors (the oil price shocks of 1973 and 1979, the Asian Crisis in 1997 and the GFC in 2007-2008).

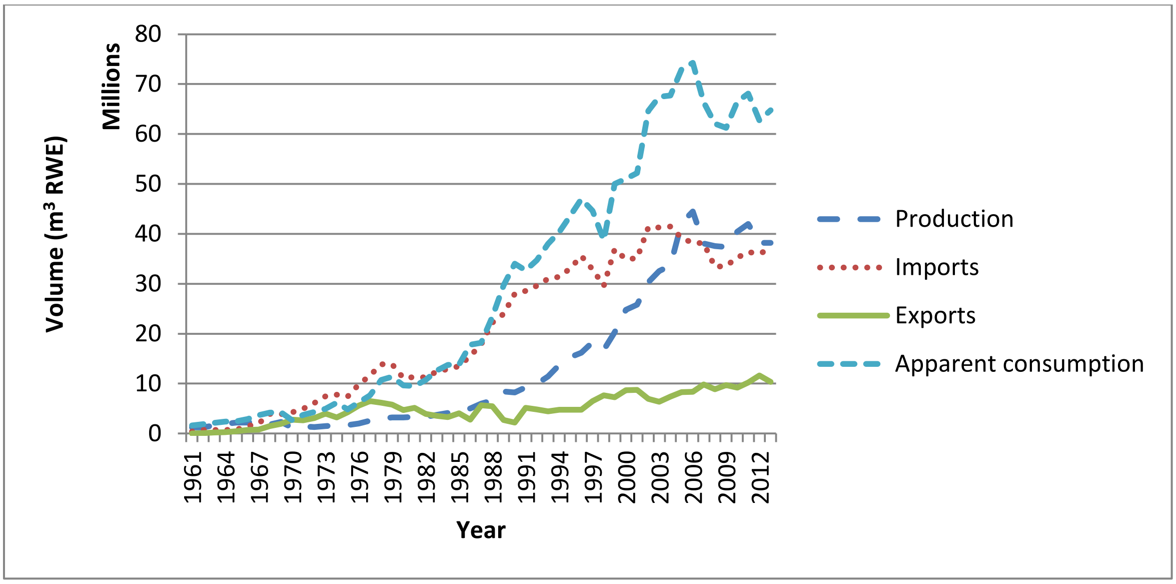

Figure 5.2. Production, imports, exports and consumption in South Korea over time.

South Korea shows a similar trend in consumption to China with strong growth from the 1970s until 2006, when consumption decreased. The average decrease in consumption of 1.3% annually between 2006 and 2013 is linked to decreases in both imports and production. Exports from the country have been increasing steadily at a modest rate since the late 1980s having been driven largely by continued investment in processing capacity (Joo et al., 2012).

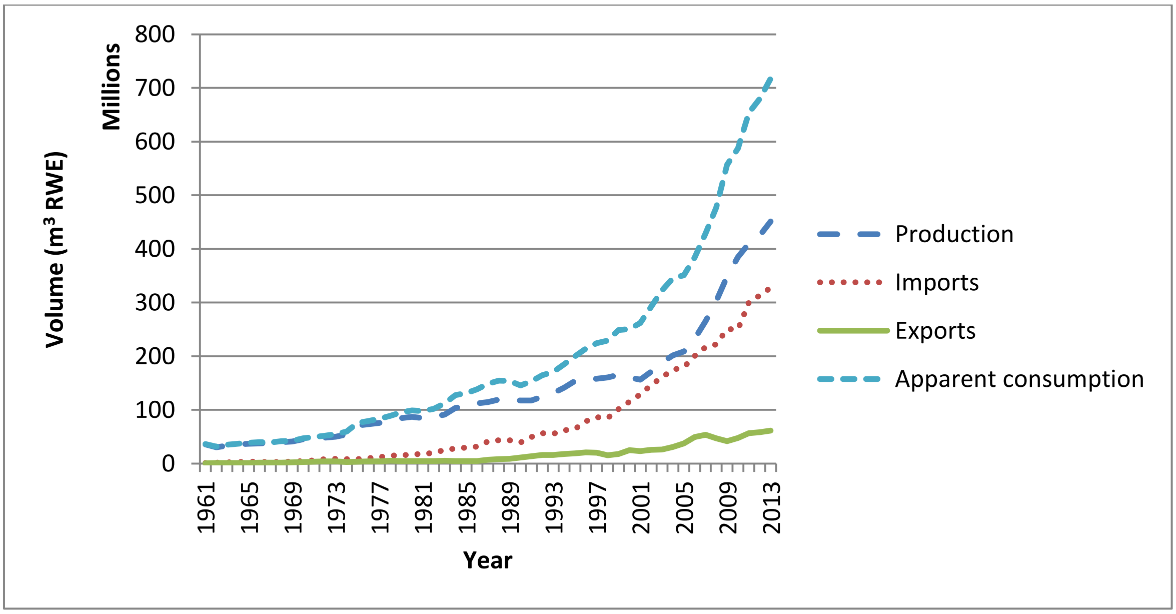

Figure 5.3. Production, imports, exports and consumption of wood products in China over time.

The consumption of wood products in China has been growing exponentially, in the past 15 years this rate has been particularly high with an average growth rate of 8% between 1999 and 2013. Around 60% of the increase in consumption has been met with increases in domestic harvest of industrial roundwood. The quantity of exports has not increased to the same extent as production. The remainder of demand has been fulfilled with imports of wood products from a vast array of countries including New Zealand. China's total apparent consumption is many times greater than the other countries studied making it particularly important for forest growers and forest product exporters.

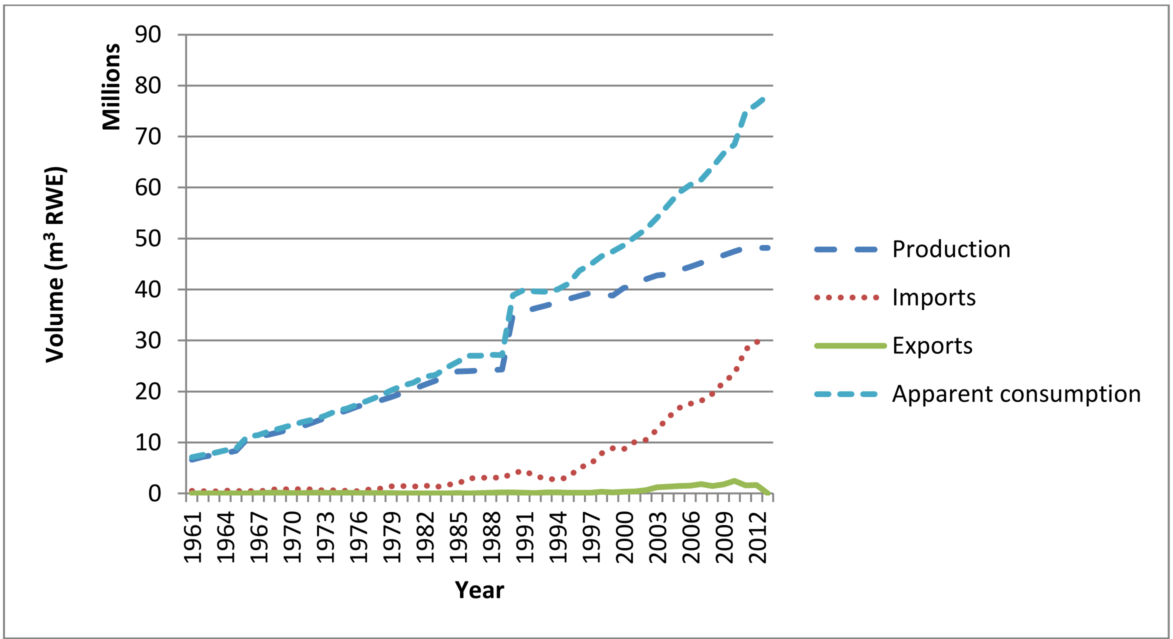

Figure 5.4. Production, imports, exports and consumption of wood products in India over time.

India has had steady growth throughout the study period. Consumption has been increasing at a more rapid rate since around 1995. The majority of this change is attributable to the increased volume of imports in the country which began picking up around the same time. There is an aggressive spike in apparent consumption between 1989 and 1990 which is the result of a sharp increase in industrial roundwood production volume which is likely to be a data error rather than an actual change in production volume. Exports from India have historically been essentially non-existent, having only really slightly picked up around the 2002 to 2012 period after which point exports reduced again. This decrease was driven by reduced exports of industrial roundwood and wood pulp products.

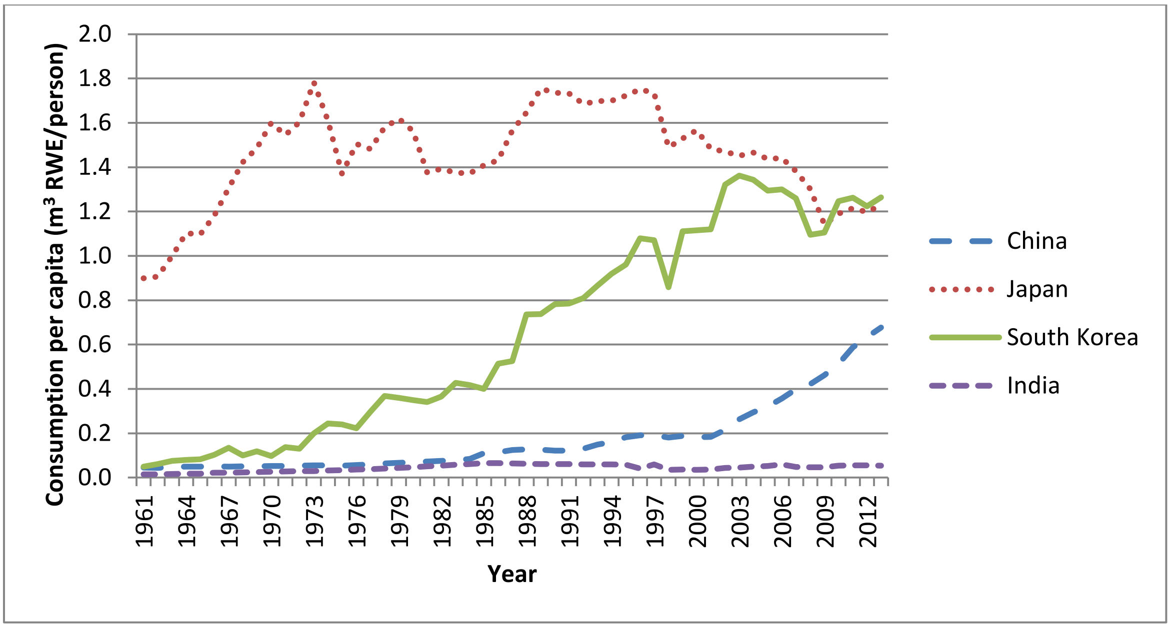

Figure 5.5. Wood consumption in the four concerned countries across time.

Removing the influence population has on the consumption of wood products allows countries to be readily compared and inferences to be made relating to their market potential. Japan being the most developed of the countries provides an estimate of the upper limit of consumption for lesser developed countries. Japan's consumption of wood products per capita peaked in 1973 at 1.78 m^3 RWE/person and has been decreasing until present. South Korea peaked at 1.36 m^3 RWE/person in 2003. China's consumption has not yet peaked and was 0.68 m^3 RWE/person in 2013. It is hypothesised that China will peak at a consumption per capita between 1.30 m^3 RWE/person and 1.8 m^3 RWE/person resulting in a potential total additional roundwood demand of between 926 million m^3 and 1.49 billion m^3 compared to 2013 levels assuming China follows a similar trend as Japan and South Korea. This is a large increase which must be satisfied by domestic production and/or imports, likely a combination of these two elements will be required due the quantity. Using the same assumptions for India, the additional roundwood requirement would be between 1.64 billion m^3 and 2.16 billion m^3 because their current consumption is low and their population sizable. This presents a potential issue for the future with possible demand greatly outweighing current production (FAO, 2015).

5.2. Composition of demand

The composition of demand across time was assessed for Japan, South Korea, China and India in order to determine if there was a change in the products demanded over time as opposed to only looking at total consumption changes over time. This was conducted to determine if there was a need to model each of the product categories separately.

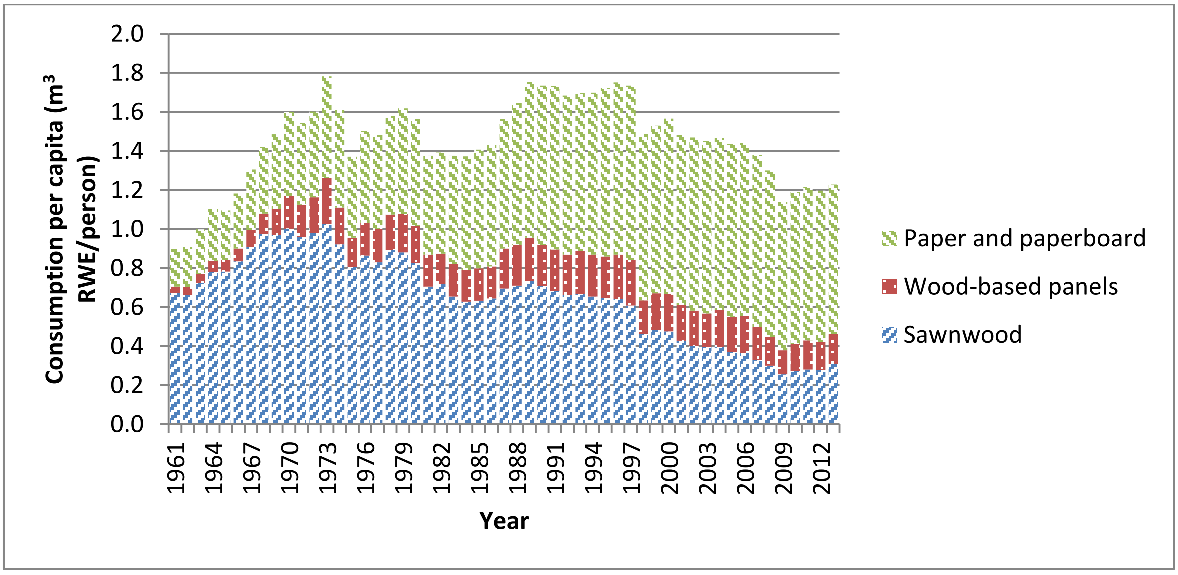

Figure 5.6. Composition of wood product demand over time in the Japanese market.

Over time in Japan there has been a shift from consumption of sawn timber to paper and paperboard. In 1961 sawn timber made up 75% of total consumption and has since reduced to 25% in 2013. Across time the consumption of wood-based panels remained relatively constant since they became a widely produced product in the early 1970s. Much of the consumption of wood-based panels in Japan is plywood which is used extensively in construction.

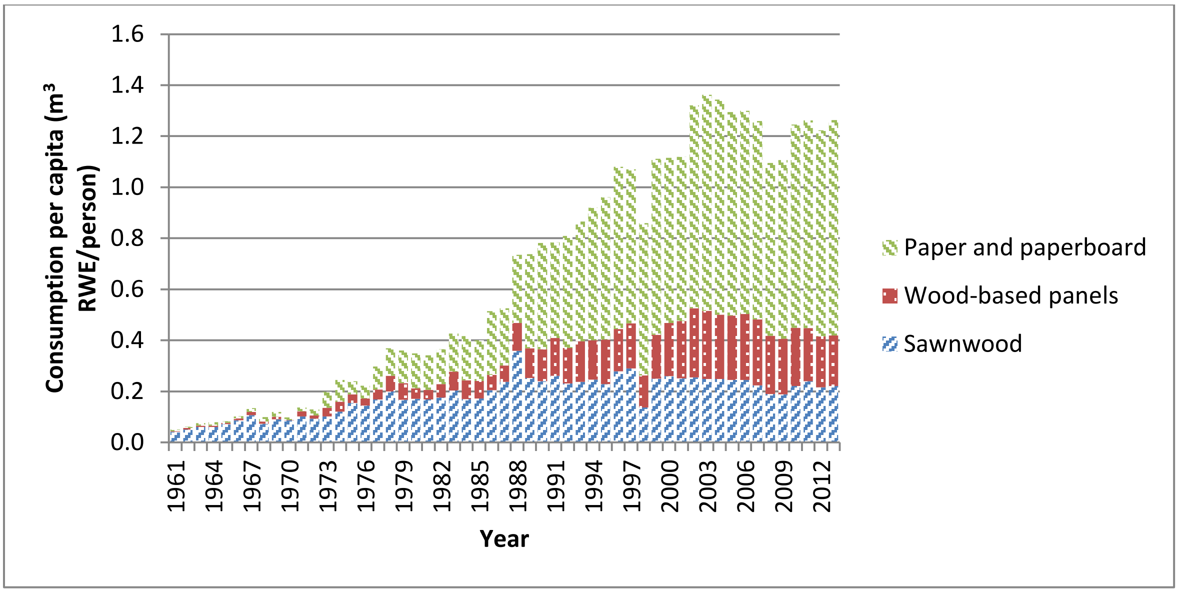

Figure 5.7. Composition of wood product demand over time in the South Korean market.

Again the same trend is seen in South Korea with only a modest increase in sawn timber consumption compared with the increase in paper and paperboard consumption. Korea is a heavy user of wood-based panels due, in part, to their strong production of MDF panels domestically. South Korea's consumption of wood-based panels is still less than China's however as China has a strong manufacturing industry which uses much of this product.

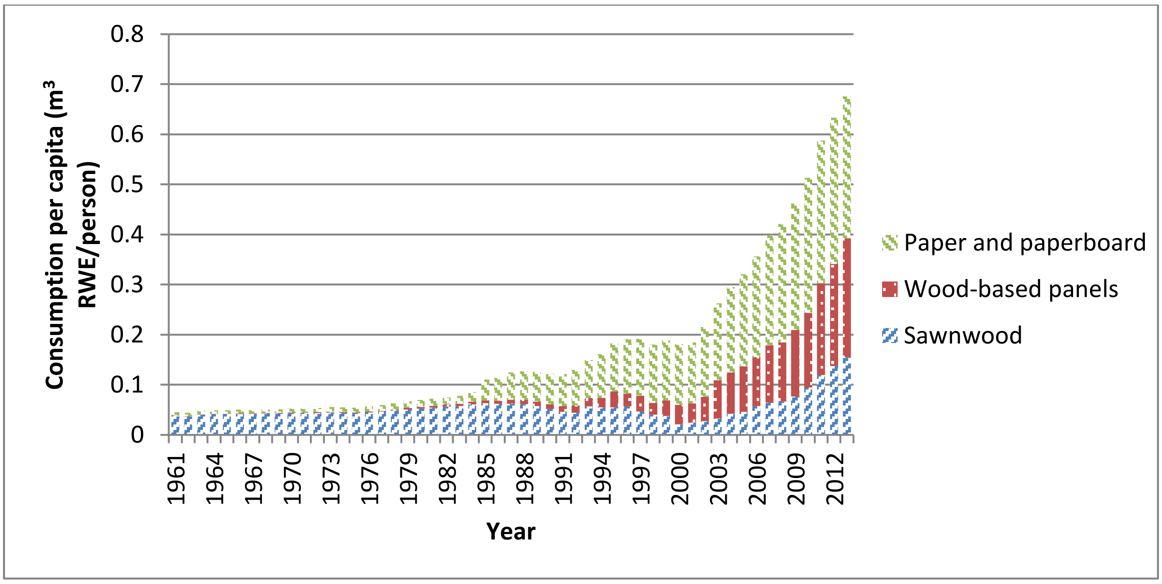

Figure 5.8. Composition of wood product demand over time in the Chinese market.

China's consumption has also shifted from predominantly sawn timber and a small proportion of paper and paperboard to a greater proportion of processed products.

These processed products essentially didn't feature until the mid-80s constituting less than 15% of total consumption in the early 60s. Now in 2013 these products make up more than 75% of total consumption.

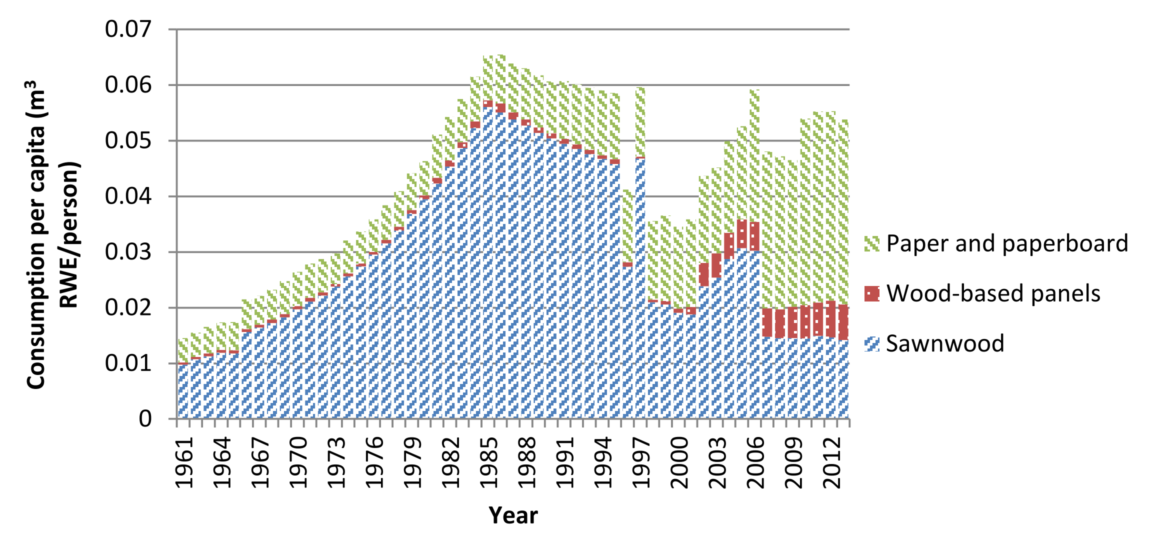

Figure 5.9. Composition of wood product demand over time in the Indian market.

India's consumption of wood products also shows the transition seen in other countries. The difference with India is that this has occurred later as they are the least developed of the studied countries. They are also atypical in the fact they have not had steadily increasing consumption over time in the same way the other countries did at the same stage of development. The data for the country also appears to be of questionable quality, with notable fluctuations year to year (notably 1997).

While India's future demand is potentially significant, it is likely that their consumption will not peak until some point long in the future as it appears that the country's development has not taken off yet. For this reason, and due to a series of discrepancies in the data available for the country, India has been excluded from further analysis.

All four countries assessed show a clear transition from solid wood products to more processed wood-based panel and paper and paperboard products. This would provide sufficient evidence to infer that as a nation's economy develops their consumption shifts to these more processed products. Reasons for this transition will be outlined in the discussion section of this dissertation.

5.3. Explanatory variables

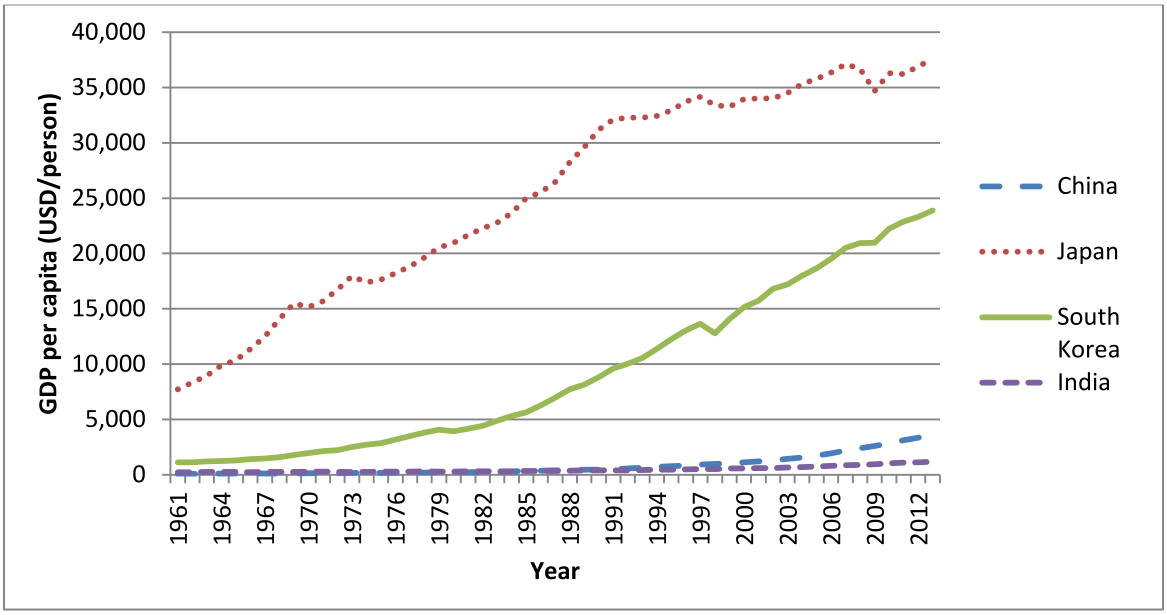

Figure 5.10. Change in GDP per capita over time for the four studied countries.

Per capita income has generally been increasing in the countries studied over the period 1961 to 2013. This was driven by the development of their economies through increased production, manufacturing, and exports of goods and services from these countries. Japan has the highest GDP per capita exceeding $37,500 USD/person in 2013. South Korea's GDP per capita was $23,900 USD/person in 2013, whereas China's was $3,600 USD/person and India's $1,200 USD/person, reflecting their respective stages of development.

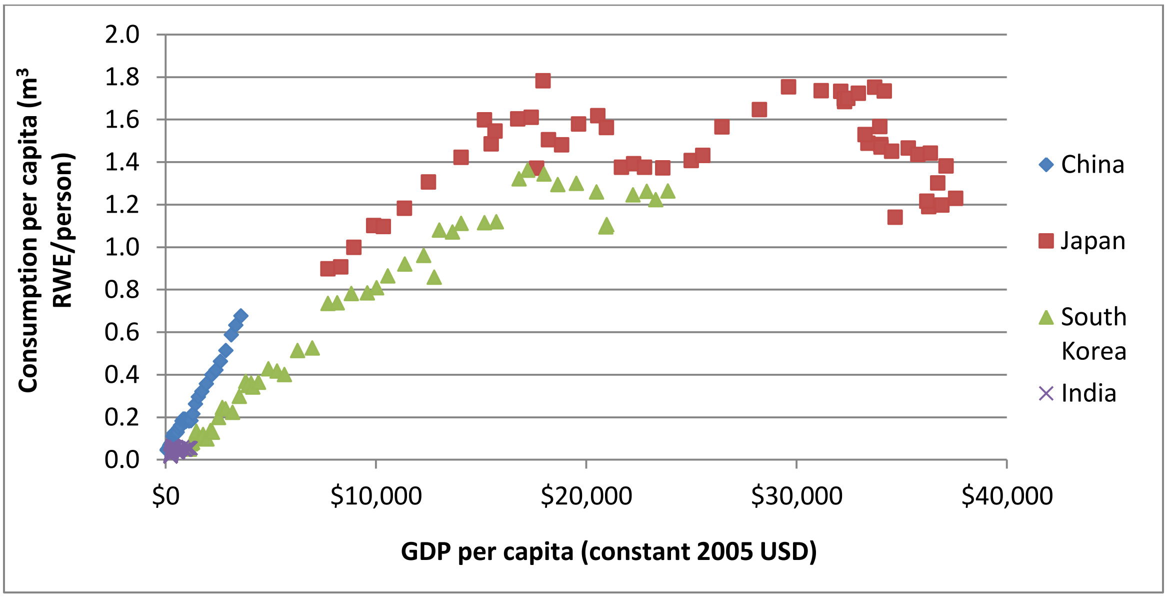

Figure 5.11. Relationship between total consumption per capita of wood products and the GDP per capita of the four concerned nations over time.

There is a clear relationship between consumption per capita and per capita GDP. In Figure 5.11 the relationship uses real GDP per capita in US Dollars so that the values are comparable. In modelling it is more logical to use the local currency of the nation as the country will respond more to changes in the value of their own currency as opposed to the US Dollar. The graph shows that as income increases, measured as GDP per capita, a country's consumption of wood products also increases except for Japan where it appears that consumption decreased at two different levels of wealth. Exactly what drives this decrease is touched on in Figure 5.12 and will be explored more deeply in the discussion section. Explaining this decrease will be important for forecasting consumption in other, less developed countries.

The graph shows that when there is an overlap between the incomes of countries consumption behaves similarly. China is clearly consuming more than South Korea did at the same level of income and there are a variety of potential explanations for this covered later. India essentially doesn't features on the graph with both low consumption and low income per capita. The dip in consumption seen around $23,000 USD in Japan is an interesting occurrence and it could be suggested that South Korea is currently experiencing this reduction.

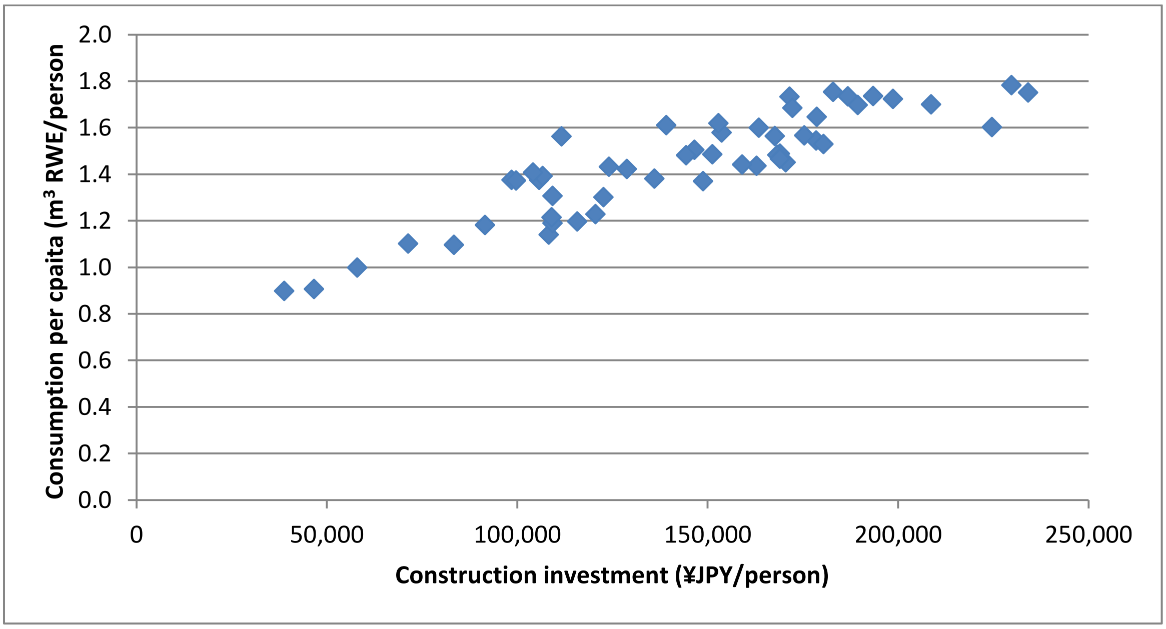

Figure 5.12. Relationship between total consumption and construction activity in Japan.

A major explanatory variable for the decrease in wood consumption in Japan is the reduction in the value of construction investment per capita in the country. Figure 5.12 shows the correlation between total consumption of wood products in Japan and construction investment per capita. The two variables are highly correlated with a coefficient of determination (R^2) of 0.80. Consumption of sawn timber in Japan has decreased by 0.7 m^3 RWE/person or almost 70% since 1973. This product category was responsible for essentially all of the decrease in the total consumption of wood products in Japan.

5.4. Modelling consumption

5.4.1. Japan

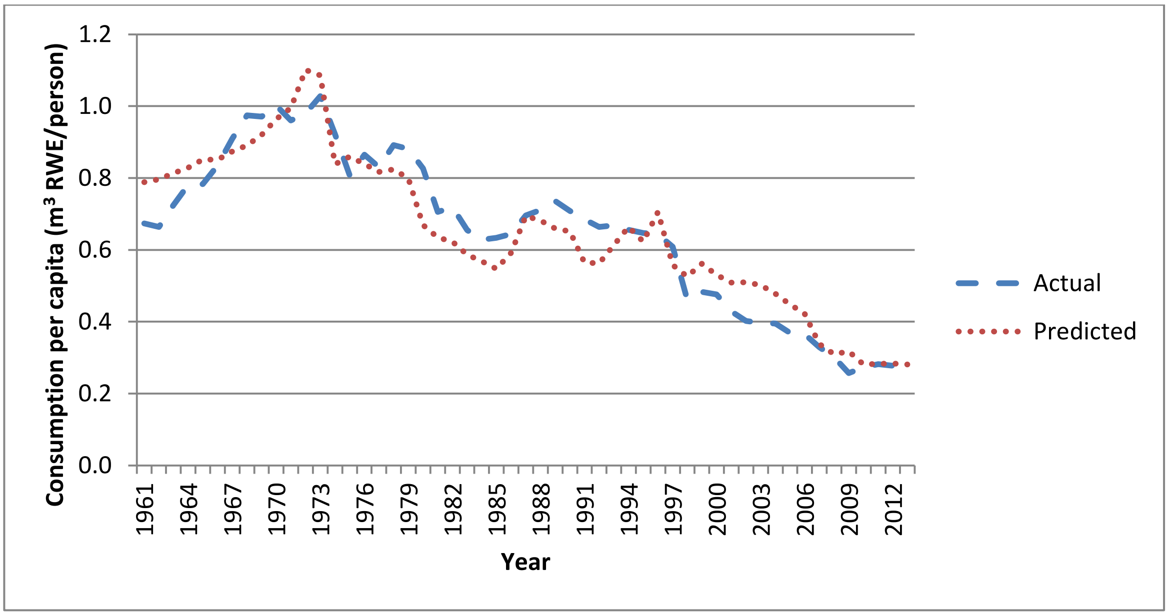

Figure 5.13. Model of actual versus predicted sawn timber consumption for Japan.

$$\begin{aligned}&\mathit{Consumption\ per\ capita\ (sawn\ timber)}\\&\quad = 0.8688^{***} + (-2.26\times 10^{-7***}\times \mathit{GDP\ per\ capita}(¥)) + (2.891\\&\quad \times 10^{-6***}\times \mathit{Construction\ investment\ per\ capita}(¥))\end{aligned}$$

Table 5.1. Diagnostics for the model of sawn timber consumption in Japan.

Diagnostic	***Value***
Degrees of freedom	50
Adjusted R^2	0.8931
F statistic	218.3
Durbin-Watson statistic	0.5993

Sawn timber consumption in Japan is driven by two major factors, GDP per capita and construction investment per capita. Japan's consumption is most strongly correlated with construction investment per capita. Over the period 1961 to 2013 actual consumption decreased from a 0.67 m^3 RWE/person to 0.28 m^3 RWE/person. Significance of predictor variables is noted by the asterisks above the coefficients, Appendix 4 describes the notation. The model has an adjusted R^2 of 0.89 and a Durbin-Watson statistic of 0.60.

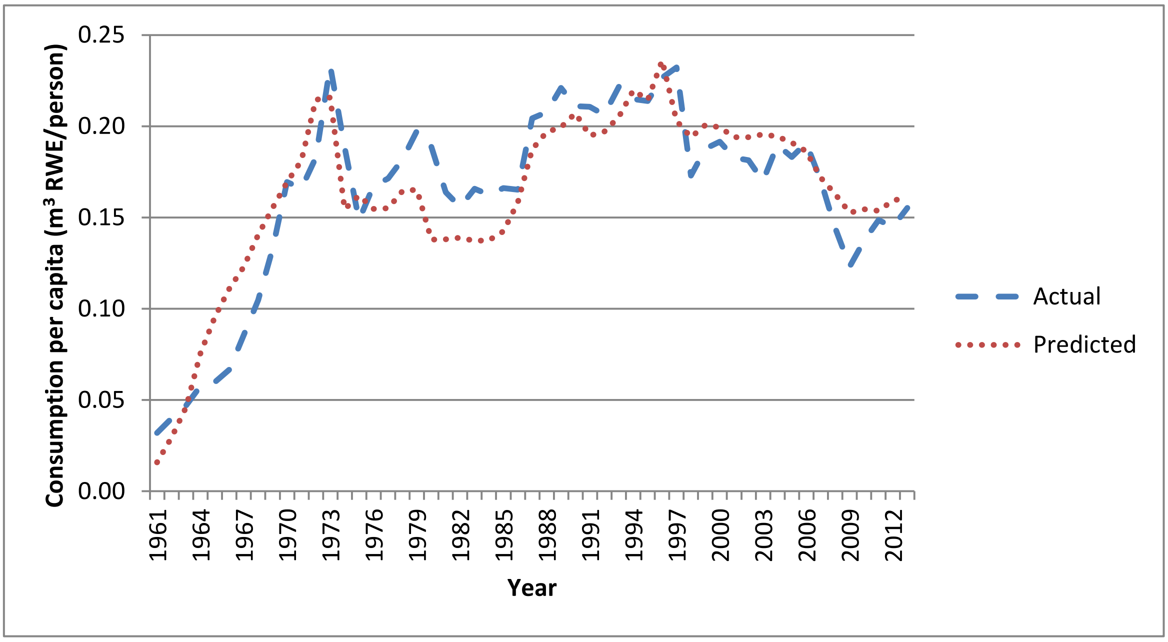

Figure 5.14. Model of actual versus predicted wood-based panel consumption for Japan.

$$Consumption\ per\ capita\ (wood - based\ panels)$$
$$= 0.0543^{***} + (-3.275 \times 10^{-7**} \times Wood - based\ panel\ price(¥))$$
$$+ (1.049 \times 10^{-8**} \times GDP\ per\ capita(¥)) + (6.858 \times 10^{-7***}$$
$$\times Construction\ investment\ per\ capita(¥))$$

Table 5.2. Diagnostics for the model of wood-based panel consumption in Japan.

Diagnostic	***Value***
Degrees of freedom	49
Adjusted R^2	0.8158
F statistic	77.77
Durbin-Watson statistic	0.7159

Consumption of wood-based panels in Japan was found to be influenced by three major factors, the real price of the product, income per capita and construction investment were all found to have a significant correlation with consumption. This model differs compared to the wood-based panel models for other countries in its inclusion of the construction activity variable. It is likely that this was significant in this model and not others due differences in the way the Japanese market uses wood-based panels. The model has an adjusted R^2 of 0.82 and a Durbin-Watson statistic of 0.72.

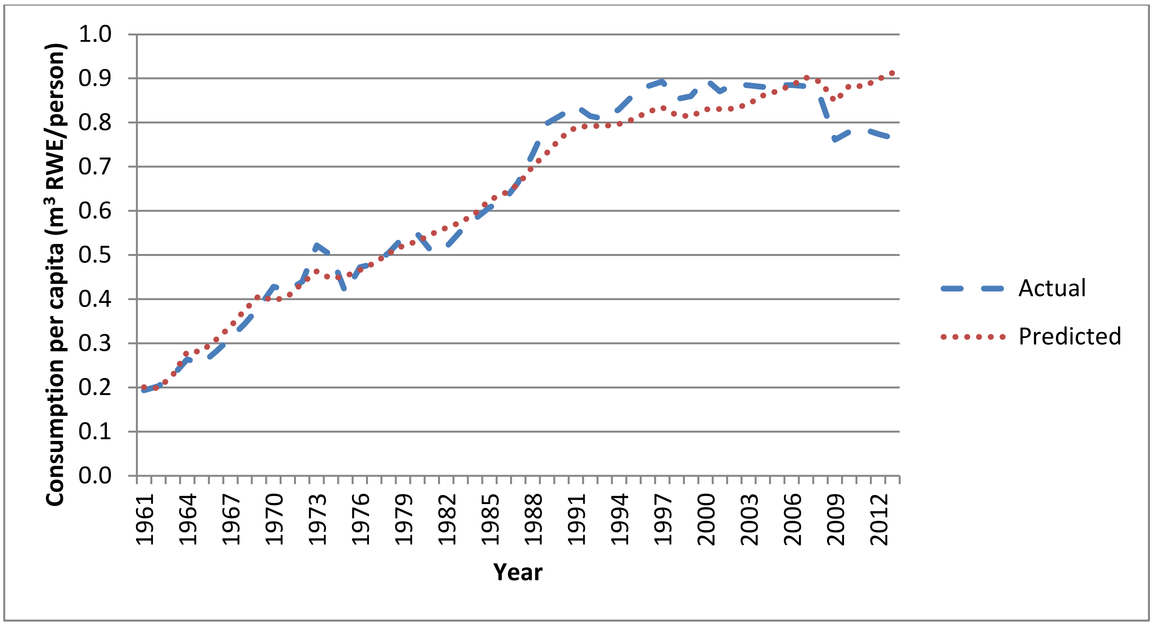

Figure 5.15. Model of actual versus predicted paper and paperboard consumption for Japan.

$$\begin{aligned} &Consumption\ per\ capita\ (paper\ and\ paperboard) \\ &\qquad = 0.06534^{\cdot} + (-7.23 \times 10^{-8} \times Paper\ and\ paperboard\ price(¥)) \\ &\qquad + (2.064 \times 10^{-7***} \times GDP\ per\ capita(¥)) \end{aligned}$$

Table 5.3. Diagnostics for the model of paper and paperboard consumption in Japan.

Diagnostic	***Value***
Degrees of freedom	50
Adjusted R^2	0.9525
F statistic	522.7
Durbin-Watson statistic	0.2793

Japan's consumption of paper and paperboard products is characteristic of many developed countries which previously had rapid increases in consumption in the past and now consumption has stabilised or is decreasing. The model developed for this product includes predictor variables of paper and paperboard price and per capita wealth. Product price was found to have and insignificant p-value at 0.30 however it was included in the model as price is a key driver of demand curves. GDP per capita has a greater influence on the consumption of paper and paperboard than the price of the product. The model has an adjusted R^2 of 0.95 and a Durbin-Watson statistic of 0.28.

5.4.2. South Korea

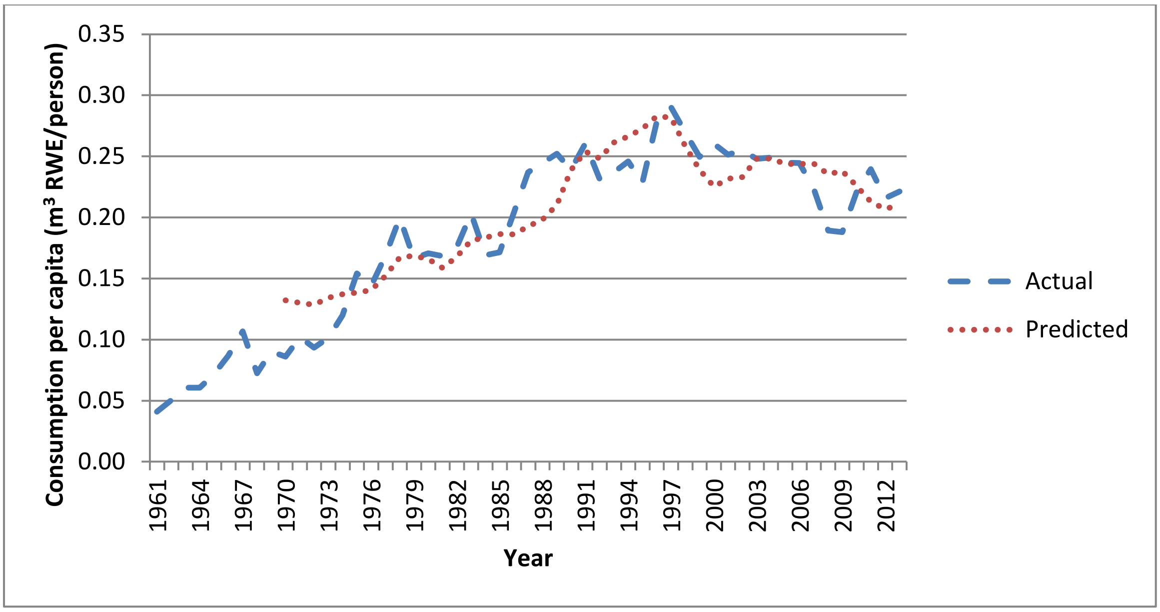

Figure 5.16. Model of actual versus predicted sawn timber consumption in South Korea.

$$\begin{aligned} &Consumption\ per\ capita\ (sawn\ timber) \\ &\qquad = 0.1051^{***} + (-3.531 \times 10^{-9***} \times GDP\ per\ capita(₩)) \\ &\qquad + (1.702 \times 10^{-7***} \times Construction\ GDP\ per\ capita(₩)) \end{aligned}$$

Table 5.4. Diagnostics for the model of sawn timber consumption in South Korea.

Diagnostic	***Value***
Degrees of freedom	41
Adjusted R^2	0.7699
F statistic	72.92
Durbin-Watson statistic	0.6659

Demand for sawn timber in South Korea tapered off over the twenty year period leading up to 2013. There was a steady increase in demand from 1961 and 1997 from a level of 0.04 m^3 RWE/person to 0.29 m^3 RWE/person. Since 1997 consumption has decreased to 0.22 m^3 RWE/person and it is possible that this trend will continue in the future as with Japan. The model produced for sawn timber consumption in South Korea used per capita wealth and value added to GDP by construction per capita as explanatory variables. The model could be based only on the period 1970 to 2013 as industry-specific GDP data was not available before 1970. The model has an adjusted R^2 of 0.77 and a Durbin-Watson statistic of 0.67. This model has the lowest R^2 of all models produced indicating that more work may be required in future to determine more suitable drivers of change in this market.

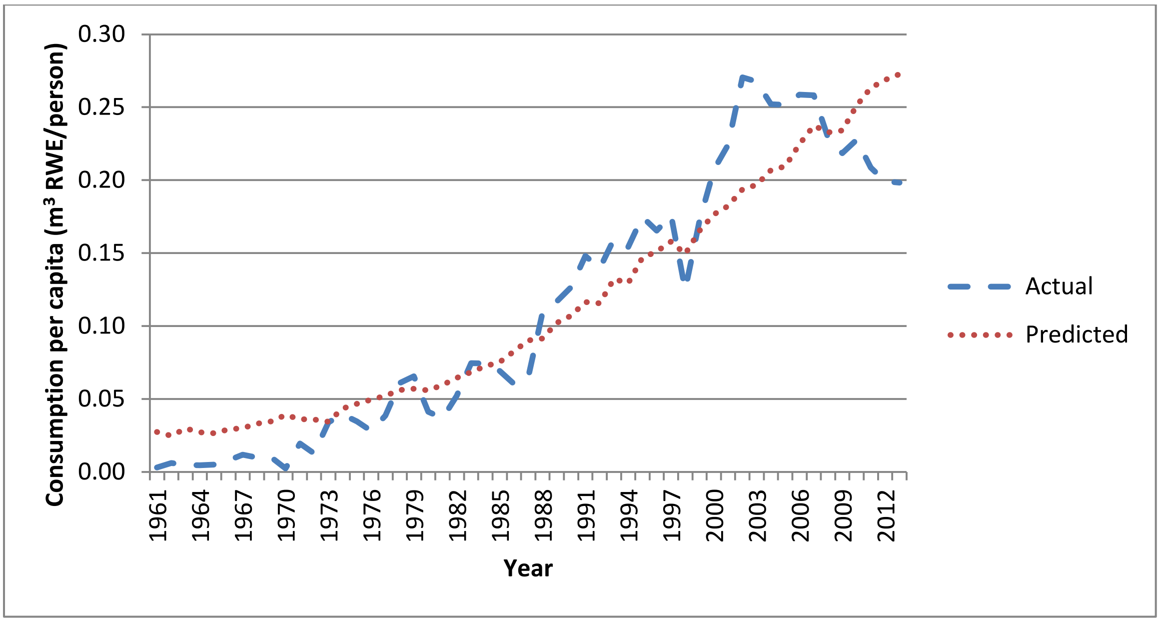

Figure 5.17. Model of actual versus predicted wood-based panel consumption in South Korea.

$$
\begin{aligned}
&\mathit{Consumption\ per\ capita\ (wood - based\ panels)} \\
&\qquad = 0.02936^{\cdot} + (-2.774 \times 10^{-8} \times \mathit{Wood - based\ panel\ price}(₩)) \\
&\qquad + (9.394 \times 10^{-9***} \times \mathit{GDP\ per\ capita}(₩))
\end{aligned}
$$

Table 5.5. Diagnostics for the model of wood-based panel consumption in South Korea.

Diagnostic	***Value***
Degrees of freedom	38
Adjusted R^2	0.8715
F statistic	136.6
Durbin-Watson statistic	0.2929

Wood-based panel consumption in South Korea has been steadily increasing over time and in recent years it has started to decline. South Korea's strong production of MDF domestically contributes to their consumption of wood-based panels being greater than Japan's. The country consumed essentially 0 m^3 RWE/person in 1961 largely due to the fact that many wood-based panel products had not been accepted into mainstream manufacturing yet. By 2003 South Korea was consuming more than Japan did at its peak.

The model for wood-based panel consumption in South Korea incorporates product price and per capita income to predict consumption. The model appears to over predict consumption early in the period before under-predicting after 1987 and again over predicting in the most recent five year period. This aside, the model maintains adequate predictive ability with an R^2 of 0.87. The model also shows autocorrelation with a Durbin-Watson statistic of 0.29.

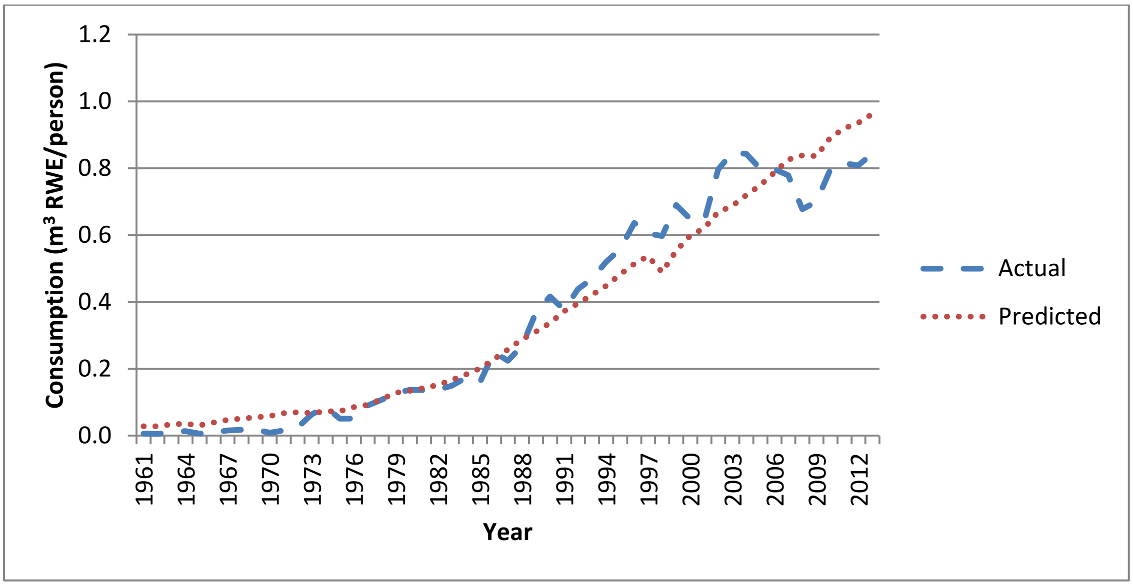

Figure 5.18. Model of actual versus predicted paper and paperboard consumption in South Korea.

$$
\begin{aligned}
&\textit{Consumption per capita (paper and paperboard)} \\
&\qquad = 9.502 \times 10^{-4} \\
&\qquad + (-1.895 \times 10^{-8} \times \textit{Paper and paperboard price} (₩)) \\
&\qquad + (3.587 \times 10^{-8***} \times \textit{GDP per capita} (₩))
\end{aligned}
$$

Table 5.6. Diagnostics for the model of paper and paperboard consumption in South Korea.

Diagnostic	***Value***
Degrees of freedom	50
Adjusted R^2	0.9484
F statistic	478.4
Durbin-Watson statistic	0.3248

Paper and paperboard consumption has increased steadily with development in South Korea. This supports evidence that consumption of paper and paperboard is closely related to income with the trend closely following the trend in GDP per capita growth shown in Figure 5.10.

The model developed to predict consumption uses GDP per capita and paper and paperboard price. The model predicts the trend in consumption excellently with an adjusted R^2 of 0.95. The model is less effective in prediction over the last five years. The model shows autocorrelation with a Durbin-Watson statistic of 0.32.

5.4.3. China

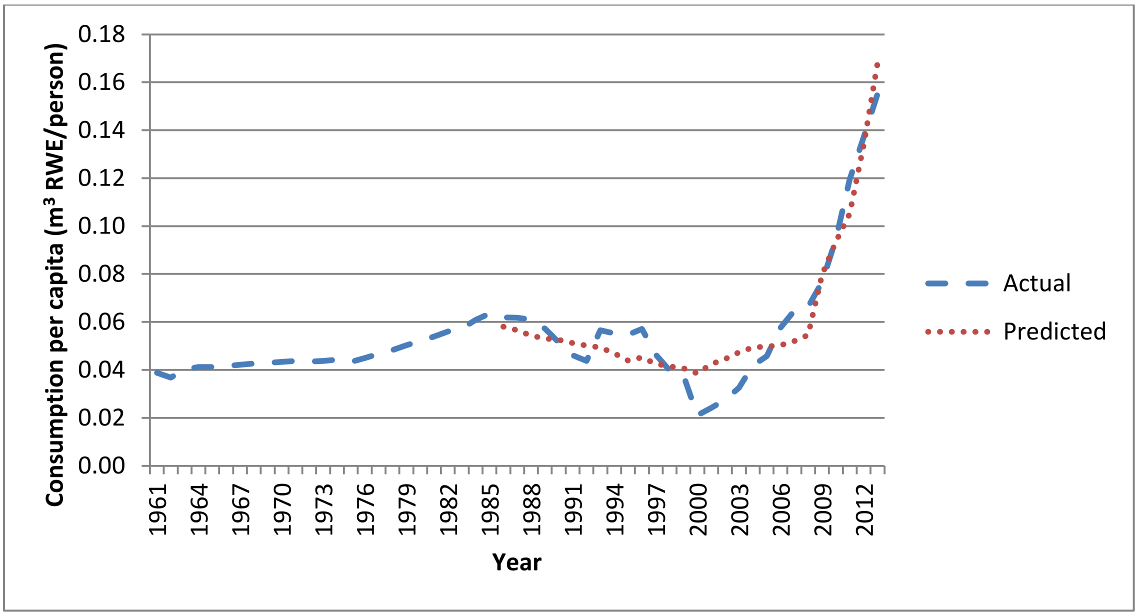

Figure 5.19. Model of actual versus predicted sawn timber consumption in China.

$$\begin{aligned} &Consumption\ per\ capita\ (sawn\ timber) \\ &\qquad = 0.07156^{***} + (-8.382 \times 10^{-6***} \times GDP\ per\ capita(¥)) \\ &\qquad + (2.583 \times 10^{-5***} \times Value\ of\ construction\ completed(¥)) \end{aligned}$$

Table 5.7. Diagnostics for the model of sawn timber consumption in China.

Diagnostic	***Value***
Degrees of freedom	25
Adjusted R^2	0.8982
F statistic	120.2
Durbin-Watson statistic	0.6192

Between 1961 and 2013 consumption of sawn timber in China increased by almost 300% from 0.039 m^3 RWE/person to 0.155 m^3 RWE/person. Consumption was fairly stable at low levels until the early 2000s when it decreased suddenly before increasing almost exponentially to 2013 levels.

The model developed to predict consumption of sawn timber in China uses GDP per capita and, as for all sawn timber models a construction activity predictor, in this case the value of construction completed. The model fits the data well with an adjusted R^2 of 0.90 and has a Durbin-Watson statistic value of 0.62 indicating undesirable levels of autocorrelation.

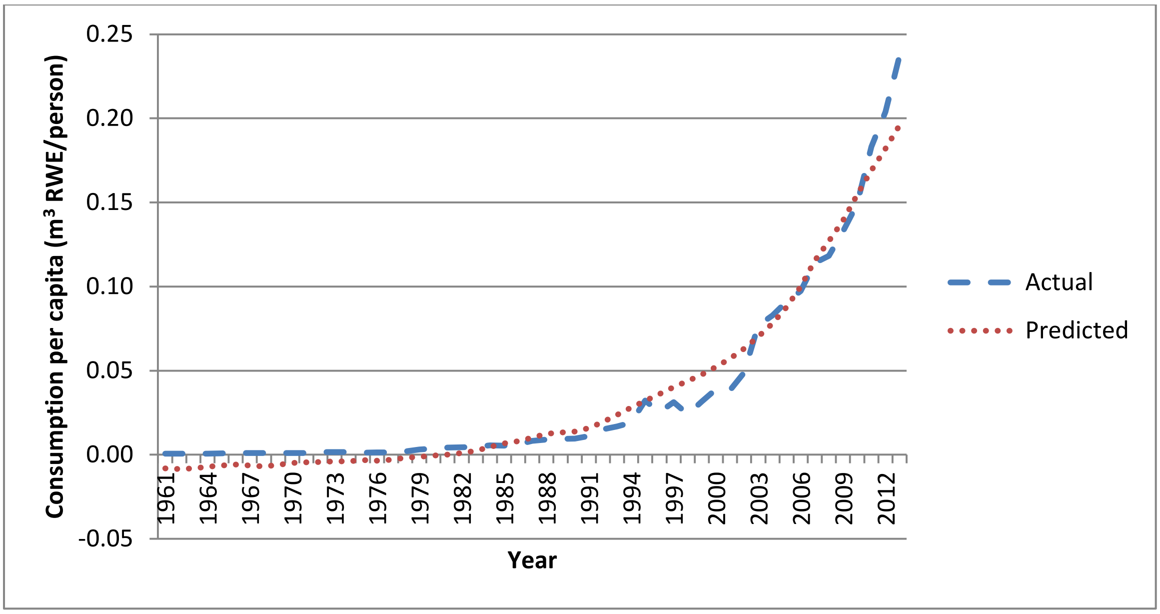

Figure 5.20. Model of actual versus predicted wood-based panel consumption in China.

$$Consumption\ per\ capita\ (wood - based\ panels) = -0.01329^{***} + (8.34 \times 10^{-6***} \times GDP\ per\ capita(¥))$$

Table 5.7. Diagnostics for the model of wood-based panel consumption in China.

Diagnostic	***Value***
Degrees of freedom	51
Adjusted R^2	0.9693
F statistic	1644
Durbin-Watson statistic	0.3436

Consumption of wood-based panels in China has increased rapidly and has reached a level greater than South Korea's consumption of the product in 2001. This is interesting as China had a much lower income per capita in 2013 ($3,583 USD) than South Korea did in 2001 ($15,732 USD) yet the two countries had the same consumption of wood-based panels. Potential explanations for this discrepancy are addressed in the discussion section of this dissertation.

In modelling China's consumption income per capita was the only predictor variable used as analysis found that all other predictor variables were statistically insignificant when it came to predicting consumption of wood-based panels. The model underestimates the consumption in the most recent data predicting 0.20 m^3 RWE/person when the actual consumption was 0.24 m^3 RWE/person in 2013. This aside, the model is generally effective in estimating consumption with an adjusted R^2 of 0.97 and a Durban-Watson statistic of 0.34 indicating adverse autocorrelation.

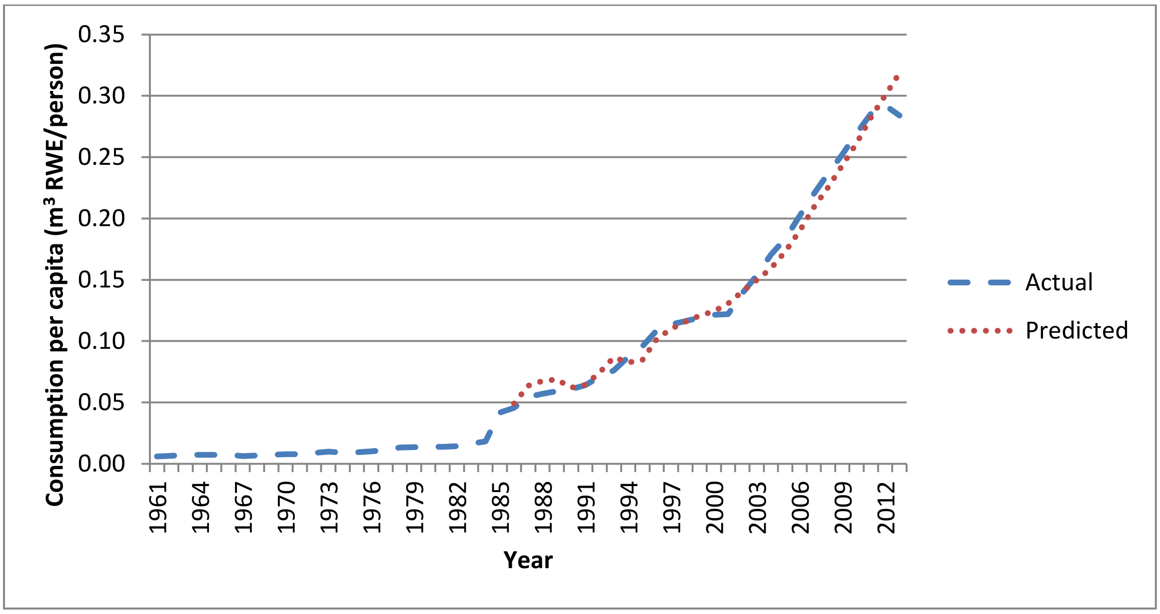

Figure 5.21. Model of actual versus predicted paper and paperboard consumption in China.

$$Consumption\ per\ capita\ (paper\ and\ paperboard)$$
$$= 0.06359^{***} + (-4.22 \times 10^{-6*} \times Paper\ and\ paperboard\ price(¥)) + (1.13 \times 10^{-5***} \times GDP\ per\ capita(¥))$$

Table 5.9. Diagnostics for the model of paper and paperboard consumption in China.

Diagnostic	***Value***
Degrees of freedom	25
Adjusted R^2	0.9826
F statistic	765.4
Durbin-Watson statistic	0.5457

China’s consumption of paper and paperboard follows a trend not dissimilar to that of the consumption of wood-based panels with very slow growth initially and then a rapid, almost exponential increase. Growth truly began in the mid-80s when, between 1984 and 1985, the consumption of paper and paperboard doubled, a point elaborated upon in the discussion section. Consumption steadily increased from this point onwards until the last period, between 2012 and 2013 when consumption decreased slightly. It is difficult to associate this with any particular factor as it only occurred over a single period and could be attributed to random variation.

The model developed for paper and paperboard consumption in China used product price and GDP per capita as predictor variables. As seen in Figure 5.21, the model predicts consumption well across the period with the greatest deviation being in the last year data was available, 2013. The result is a model with an excellent representation of the data with an adjusted R^2 of 0.98 and, as with all of the models it has an undesirable level of autocorrelation with a Durbin-Watson statistic of 0.55.

5.5. Forecasting consumption in Japan

The overarching goal of modelling consumption in the studied countries was to use the models developed to produce forecasts for the different product categories. In this section forecasts are presented for the three aggregate product categories in Japan, sawn timber, wood-based panels and paper and paperboard. The forecasts presented herein should be used as an example of how this research can be utilised, using it to make investment and marketing decisions however is possibly somewhat hasty. Further work is required in developing accurate forecasts of explanatory variables and using these to better estimate future consumption.

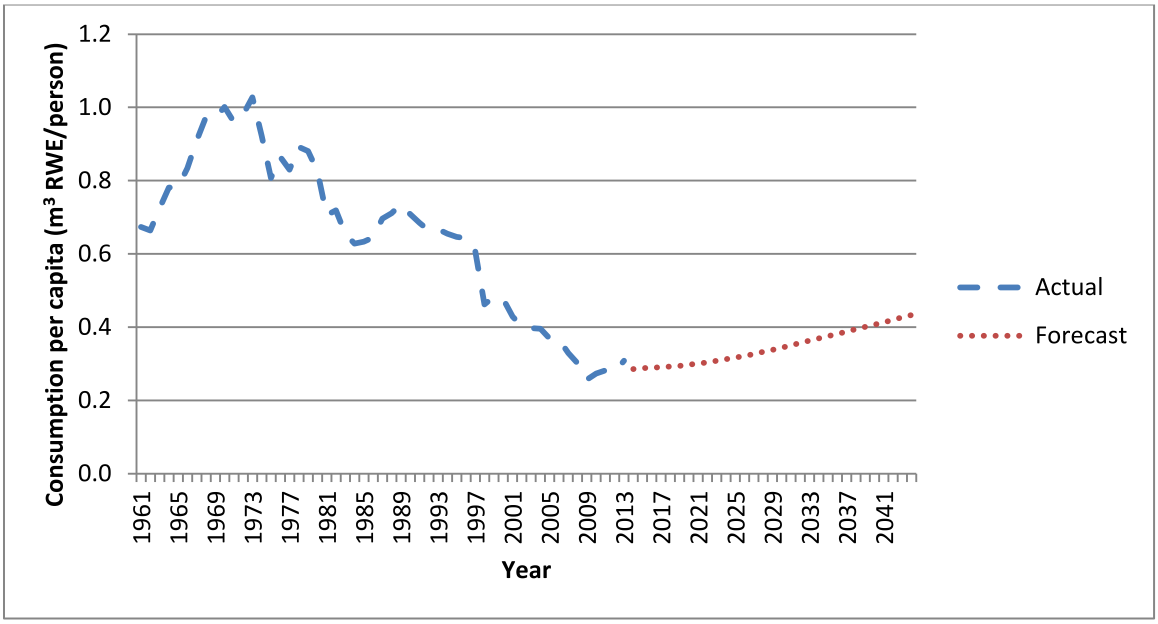

Figure 5.22. Actual sawn timber consumption and an example forecast to 2044 for Japan.

The forecast data from 2014 to 2044 used an estimated GDP per capita growth rate of 0.2%/annum across the period reflecting Japan's already high level of development (IMF, 2015). Furthermore, construction investment was assumed to follow this same trend. This produced an increasing forecast for the consumption of sawn timber in Japan as construction investment has a greater positive influence on consumption compared to the negative GDP per capita influence which is an order of magnitude smaller.

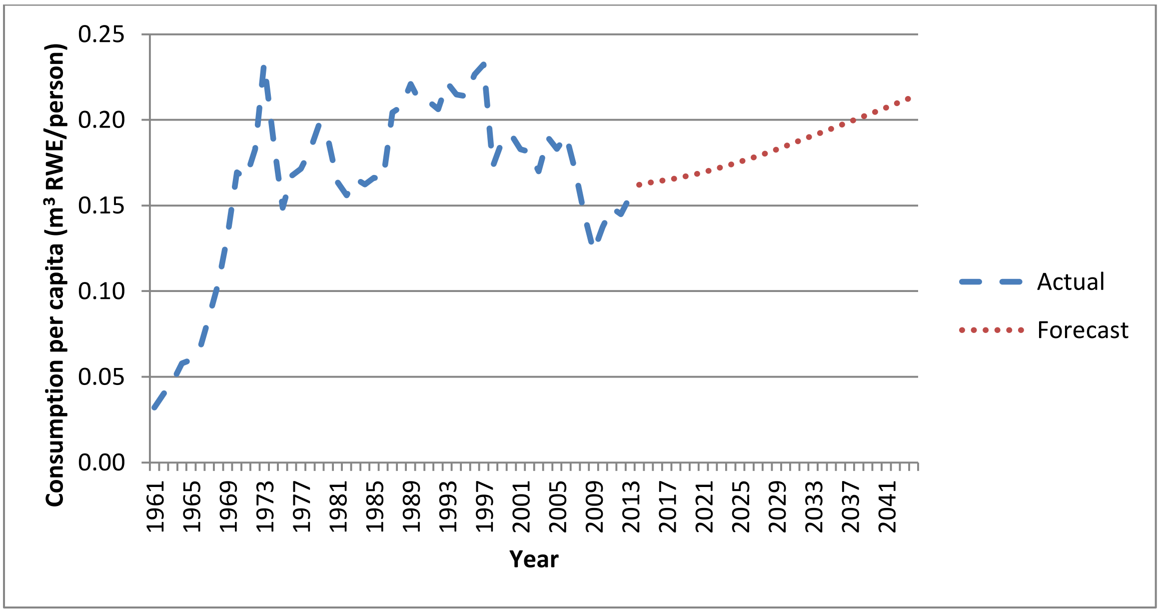

Figure 5.23. Actual wood-based panel consumption and an example forecast to 2044 for Japan.

The forecast for wood-based panel consumption in Japan assumed the same per capita increase in GDP and construction activity as for sawn timber, 0.2%/annum. This model also used product price which was assumed to remain constant in real terms across the forecast period. The model shows a steady increase in the consumption of wood-based panels over the thirty year period. Consumption is forecast to increase to 0.21 m^3 RWE/person by 2044 up from 0.16 m^3 RWE/person in 2013. As with sawn timber this increase is driven largely by the anticipated increase in construction activity.

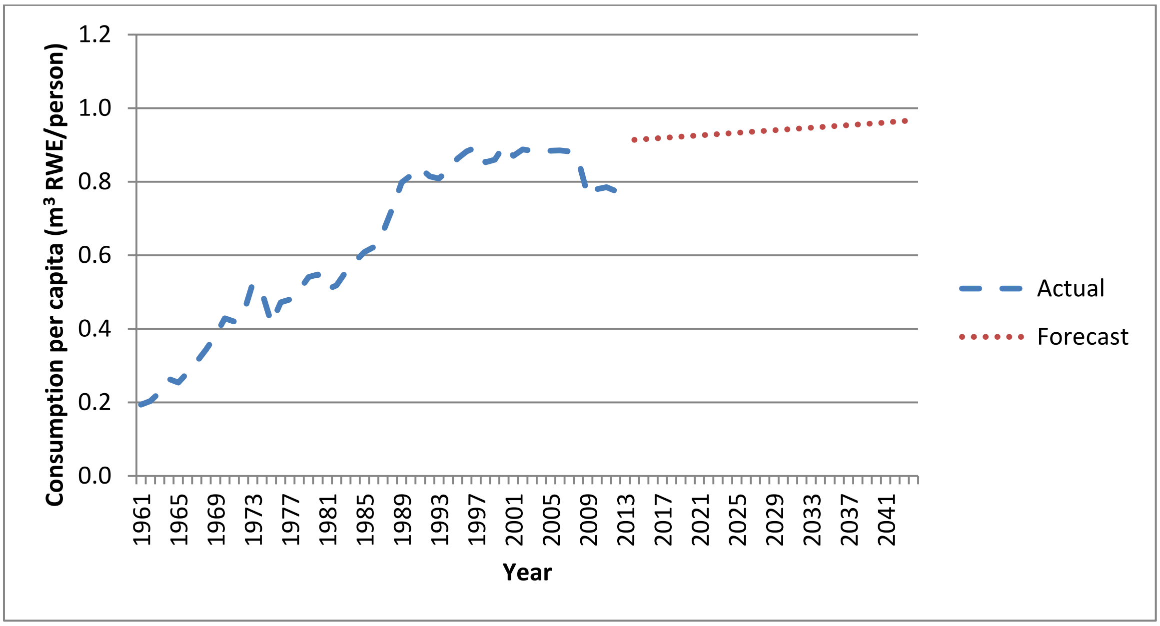

Figure 5.24. Actual paper and paperboard consumption and an example forecast to 2044 for Japan.

A forecast of paper and paperboard consumption in Japan is also included in the graph for the period 2014 to 2044. The model predicts that paper and paperboard consumption will remain relatively constant over the thirty year period only increasing slightly. There is potential however that the model is over predicting consumption as there are a variety of factors now decreasing demand for communication paper categories, a point expanded upon in the discussion section. The forecast estimates a 25% increase over the observed value in 2013 of 0.77 m^3 RWE/person. The model does not predict the decrease in recent years well and is over predicting consumption at 0.91 m^3 RWE/person in 2013, 18% higher than the actual value. The model estimates that by 2044 Japan's consumption of paper and paperboard products will be 0.96 m^3 RWE/person.

The total consumption of all wood products in Japan is estimated to be 1.60 m^3 RWE/person by 2044. Under this assumption and using population projections, estimated to be 112.6 million people in 2044, the total volume of roundwood required to service the individual product demand was found to be 180.4 million m^3 (FAO, 2015).

6. Discussion

Consumption per capita

Changes in the population of a country can influence the level of consumption in that country. By removing the influence of population consumption data and producing a consumption per capita value it allows countries to be compared. The same methodology has to be applied to the values of explanatory variables as these too are influenced by changes in population.

Japan's high level of development makes it a good estimate of the potential upper limit of wood consumption in other developing Asian countries. From the analysis it appears that Japan has been through a cycle of consumption from increasing early in the period, to fairly stable in the middle before finally decreasing in the recent past. It appears that South Korea has now completed the growth stage and is possibly moving into the stable stage of the cycle. China appears to be in the growth stage, possibly around a third of the way through this phase. The steeper growth of consumption relative to GDP per capita compared with other countries for China could mean that China will reach its peak at a lower level of income than for the other countries studied.

Japan and South Korea's consumption appear to have peaked at different levels, Japan at 1.78 m^3 RWE/person and South Korea at 1.36 m^3 RWE/person as identified in Figure 5.5. This discrepancy may be the result of cultural differences between the two countries resulting in differences in the way the countries utilise wood products. The Japanese culture is well-known for its heavy consumption of wood products, favouring its visual appearance and versatility (Henrichsen & Bauer, 2004). The South Korean culture does not value wood in the same way the Japanese culture does, South Koreans see wood as more of a utility product (Joo et al., 2012). This cultural difference sees Japan consume a greater volume of wood products per capita than other Asian nations.

Product composition

The analysis found that there was an evident change in the composition of product demand with development shifting from solid wood products to more processed products. Drivers of this change were found to be different between countries and between product categories. The key driver of change in sawn timber demand was found to be the construction activity regardless of country. When a country is quickly developing their construction industry follows suit with comparable growth resulting in demand for building materials, of which a major component is sawn timber. When a downturn is seen in construction, consumption of timber reduces as for Japan. The decrease in total consumption of wood products in Japan was driven almost exclusively by this decrease in sawn timber.

The trend in reducing consumption per capita for Japan is driven directly by the downturn in the construction industry however the root cause is the stagnant economy in Japan. This began in the 1990s when Japan's stock market crashed causing many financial institutions to go bankrupt and seek bailouts from the government, which they received. The crash led to the popular term "The Lost Decade" and then, "The Lost Two Decades" after two decades of losses in GDP. This has meant that the construction industry was left without capital investors and the activity in the sector steadily diminished (Anonymous, 2009).

China's wood-based panel consumption per capita was equivalent to South Korea's consumption at a level of income almost three and a half times less than South Korea's. China is a heavy user of wood-based panels and this can be attributed to its strong manufacturing and construction industries which utilise much of this product.

Paper and paperboard consumption per capita is strongly correlated with per capita GDP and this was evident in the analysis conducted in this dissertation. All countries assessed showed strong positive correlations with GDP per capita except at the highest levels of GDP. The decrease in consumption seen in paper and paperboard is likely to be a result of reducing demand for communication papers. Communication papers include printing and writing papers and newsprint. The consumption of these products is likely decreasing due to the technological change occurring worldwide. More people in these economies are accessing information via electronic means, whether it be news via the internet, or dialogue by email, these changes are reducing the demand for paper. Other sub-categories of paper and paperboard are either increasing or remaining constant; these include packaging papers, household and sanitary papers, and recovered paper. Packaging paper consumption is likely to be closely linked to export activity in a country with many products requiring packaging prior to shipment in addition to domestic consumption. Household and sanitary paper consumption remains stable once developed as the product becomes a necessity regardless of income (Transparency Market Research, 2012).

GDP per capita over time

Japan's stagnating economy was shown clearly in Figure 5.10 beginning at the start of the 1990s for reasons outlined earlier. Part of the reason the country has had any growth in GDP per capita at all is the population in the country is declining, a trend seen in many highly developed nations (FAO, 2015). Japan's economy was influenced more than any of the other assessed countries in the Global Financial Crisis (GFC) as they are heavily dependent on exports for income.

South Korea had strong economic growth through the 1960s to the 1980s thanks to strategy developed focusing on exports of labour-intensive manufactured products. South Korea experienced a decrease in per capita income between 1997 and 1998 due to the Asian Financial Crisis which caused the South Korean Won to depreciate heavily (Koo & Kiser, 2001).

Rapid growth has not yet begun in India with the country only increasing GDP per capita modestly in the past 53 years. Total GDP has actually increased significantly over time from $61.5 billion USD in 1970 to $1.94 trillion USD in 2013 however their population has expanded at a similar rate meaning that per capita income has not increased notably. India has appeared to be a promising market for New Zealand's log exports for quite a while now, but the country's growth has never really taken off. Exactly when this will occur is difficult to determine with forecasts of GDP not showing rapid growth until around 2030, this is however highly speculative (OECD, 2014).

Wood consumption vs GDP

It appears from Figure 5.11 that the gradient of China's growth of wood consumption relative to GDP is much steeper than South Korea. Furthermore if the trend in China was extrapolated its consumption would appear to be greater than Japan's for the same level of income. It is difficult to say whether China will continue this trend and reach a peak level of consumption at a lower income than the other assessed countries or whether their rate of increase in consumption will slow, reaching a peak at around the same level of income as the other countries. As outlined above, the Japanese culture uses wood heavily so the question must be raised, why is China consuming so much more than these other nations at the same level of income per capita? A potential explanation for this difference between countries is the political situation in China. China's communist political system allows the government to make decisions with little input from the public. This means that if the country needs land to build new industrial facilities it can claim land, if it needs workers to operate these facilities it can tell its people to do so, and any opposition to such developments is quickly silenced. This means that the country's development has not been held back by so called 'red tape' which could have limited the rate of growth of some other countries. During Japan and South Korea's development both nations were democracies ensuring that everyone had the chance to be heard and opposition was accepted. While communism has potentially been beneficial for the economic growth of China, questions are still being raised about the human cost that is associated, with families being displaced, poor working conditions and unfair remuneration.

The slump in consumption Japan experienced around $23,000 USD was interesting in that there is no clear explanation for its occurrence. For Japan, this occurred in the early to mid-1980s, a time when there was no clear driver of this decreased consumption. More work is required to determine the cause of this decrease and to conclude whether South Korea is likely to experience this slump also.

Japan experienced a decrease in consumption per capita with increasing income per capita beyond a certain level of income. It is theorised that other markets are likely to follow this trend. This finding agrees with the relationship proposed by Kayo et al. (2015)

which suggested that a Kuznets curve existed between per capita income and per capita wood consumption.

Models and forecasts

Disaggregation of the aggregate paper and paperboard product category will improve model predictions as some products within the aggregate will have reduced demand while others will remain constant. As seen in the models, all failed to predict recent downturns in consumption, likely related to reducing demand for communication papers. While the models for historic paper and paperboard consumption are excellent in prediction being able to accurately model the future may require the categories to be accounted for separately.

Wood-based panels posed difficulties in modelling, particularly in Japan. It is likely that this stems from the different ways in which the markets use wood-based panels. The wood-based panel aggregate category consisted of six different components in 2013 which can be categorised into structural and non-structural panels. Japan and China use greater volumes of structural panels like plywood in construction while South Korea consumes large volumes of MDF in manufacturing. These products are used very differently and as a result different drivers could be associated with each. Future work could focus on disaggregating this category and modelling each component separately.

Sawn timber was found to be one the most difficult to model product categories. The model developed for sawn timber consumption in South Korea had the lowest adjusted R^2 of any of the models produced. This outlines a potential avenue for further work into looking for more drivers of change in this economy in particular. Other sawn timber models have R^2 values of around 0.90 meaning that there is likely something significant other than income per capita and construction GDP per capita driving change in South Korea.

Sawn timber consumption is negatively correlated with income per capita in all of the countries assessed indicating that with development countries consume less sawn timber. The negative nature of the relationship is likely a result of changes in the way buildings are constructed with increased development. At lower levels of development, suburban living dominates with individual low-rise houses being constructed for a small number of families. These types of structures are well suited to timber construction. With further development and increasing population density dwellings become apartment style and high-rise buildings become more common. Only in recent years with the introduction of cross-laminated timber building systems has it been possible to construct these types of structures from wood, though this is still a niche market. As a result consumption of sawn timber decreases and consumption of alternatives such as concrete and steel dominates.

All of the models produced showed adverse levels of autocorrelation or serial correlation. Autocorrelation is a measure of the relationship between errors in a model. It is unsurprising that autocorrelation was identified in the time series data as each observation is almost certainly linked to the previous. Future work should look at using autoregressive models to better account for the autocorrelation which exists in the data.

The models developed for predicting Japan's consumption should be considered only an example of the potential use of this research and not accurate measures of consumption. Forecasting was conducted using the best information available however concerns were raised over the forecast growth of Japan and so a unique forecast of GDP per capita was produced. With more time and resources it would be possible to solidify accurate forecasts of explanatory variables and produce estimates which could be used reliably by industry.

6.1. Limitations

Work of the sort conducted in this dissertation requires a wide variety of assumptions to be made which lead to potential limitations of the research. The nature of predicting future trends in consumption often makes estimation more art than science, with such a vast array of variables influencing how markets behave. A few of the limitations of the research are included herein.

The methodology used to convert product volumes to roundwood equivalent volumes used conversion factors from a UNECE document produced in 2010 which was based on the collection of conversion values between 2008 and 2010. While these factors reflect the current conversion rate accurately it is likely that they under predict the roundwood equivalent volume earlier in the period. The reason for this discrepancy is largely due to technological change which has seen processors become more efficient at converting raw products into end-products. To a lesser extent there has also been a change in the forest resource, based on harvesting natural forest in the past and now moving towards a more homogeneous plantation resource in many parts of the world, improving conversion rates.

Over the period assessed, FAO changed the way they aggregate products several times. Three categories of roundwood products were aggregated into an industrial roundwood category in 1990 and the compressed fibreboard category was disaggregated in 1995 into three separate categories. This meant that at different periods of time different conversion factors were used depending on the level of aggregation FAO used. This was a reasonable methodology as conversion factors were available for both the higher and lower levels of aggregation.

The models produced through this research are designed to predict the consumption of the high level aggregate product categories. As outlined in the discussion section this led to difficulties in modelling some product categories and disaggregation would be favourable to produce more effective models. This factor could lead to inaccurate predictions if, as for paper and paperboard one product within the aggregate responds differently to drivers of change.

A key issue identified when undertaking forecasting work is basing forecasts of wood consumption on forecasts of explanatory variables, this results in wood consumption estimates only being as accurate as the forecasts available. This issue is further compounded by the publication date of the forecast data. For example some of the most recent published forecasts for China (2014) are possibly too optimistic now that the Chinese economy has begun to slow. The simplest method of solving this is to produce GDP estimates oneself. This was conducted on only a very basic level for this research. Work in future should focus more on forecasting future trends now that drivers of change have been fairly conclusively determined.

7. Conclusions

A clear relationship has been drawn between the development of a country and the type of products which they are consuming. Consumption of paper and paperboard and wood-based panel products in all countries assessed increased proportional to total consumption while proportional sawn timber consumption decreased considerably. It is proposed that this is related to fast developing countries pouring resources into construction of new buildings and infrastructure which once constructed are likely to service the country for a long period and as a result demand for timber products decreases.

A country's wealth was found to have the most profound influence on the wood consumption of a country with all product categories being significantly correlated with GDP per capita. Price was also found to be a major driver of consumption for wood-based panel and paper and paperboard products. Sawn timber consumption was however not significantly influenced by price, instead construction activity was found to have the most profound impact.

Estimates of future consumption are, for now speculative with more work being required to improve models further and prepare forecasts which are more reliable to base projections on. Disaggregation of the broad aggregate categories modelled here would be a logical first step in further modelling.

The research identified that there is a clear need for New Zealand to re-evaluate its market positioning and consider what type of domestic processing capacity needs to be established in order to cater to the needs of our most important markets in the future.

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9. Appendices

9.1. Appendix 1

Appendix 1. Table presenting the assumptions and accuracy of previous authors' estimates of consumption.

Author	Country	Product	Assumed GDP growth rate	Actual GDP growth rate	Year	Predicted consumption (millions)	Actual consumption (million)	Error
Zhang et al. (1997)	China	Paper and paperboard	6%	10.6%	2010	81.7 t	96.8 t	-16%
		Paper and paperboard	9%	10.6%	2010	106.9 t	96.8 t	10%
		Wood-based panels	6%	10.6%	2010	26.6 m^3	95.9 m^3	-72%
		Wood-based panels	9%	10.6%	2010	34.8 m^3	95.9 m^3	-64%
		Sawn timber	6%	10.6%	2010	14.1 m^3	52.6 m^3	-73%
Buongiorno and Grosenick (1977)	World	Paper and paperboard	3.4%	7.7%	2010	937.3 t	393.8 t	138%
		Sawn timber	3.4%	7.7%	2010	1,549.2 m^3	372.1 m^3	316%
		Industrial roundwood	3.4%	7.7%	2010	2,790.1 m^3	1,651.1 m^3	67%
D. He and Barr (2004)	China	Paper and paperboard	-	10.2%	2010	68.5 t	96.8 t	-29%
		Wood pulp	-	10.2%	2010	59.6 t	19.6 t	204%
H. He and Xu (2011)	China	Sawn timber	8%	10.2%	2013	171.0 m^3	87.8 m^3	95%
Whiteman and Brown (2000)	World	Industrial roundwood	-	5.4%	2010	1,872 m^3	1,651.1 m^3	13%
		Sawn timber	-	5.4%	2010	501 m^3	372.1 m^3	35%
		Wood-based panels	-	5.4%	2010	180 m^3	355.7 m^3	-49%
		Wood pulp	-	5.4%	2010	208 t	173.0 m^3	20%
		Paper and paperboard	-	5.4%	2010	394 t	393.8 t	0%

9.2. Appendix 2

Appendix 2. Table of sources of data used in the analysis of consumption trends, model formulation and forecasting.

Data	Country	Source
Production, imports and exports wood products	All	FAO (2015)
Conversion factors	All	FAO (2010a)
Population	All	FAO (2015)
GDP per capita	All	IMF (2015)
GDP deflator	All	IMF (2015)
GDP by industry	China	National Bureau of Statistics of China (2015)
	Japan	Statistics Bureau Japan (2015)
	Republic of Korea	KOSIS (2015)
Product prices	All	FAO (2015)
Producer price index	Japan	Statistics Bureau Japan (2015)
	Republic of Korea	KOSIS (2015)
Urban population	All	The World Bank (2015)
Value of construction	China	National Bureau of Statistics of China (2015)
	Japan	Statistics Bureau Japan (2015)
	Republic of Korea	KOSIS (2015)
Total value of exports	China	National Bureau of Statistics of China (2015)
	Japan	Customs and Tariff Bureau (2015)
	Korea	KOSIS (2015)
Forest area	All	The World Bank (2015)
GDP forecasts	All	OECD (2014)

9.3. Appendix 3

Appendix 3. Table of the conversion factors used to derive roundwood equivalent volumes from product volumes.

	Conversion factors
Roundwood (m^3)	
Sawlogs and veneer logs	1
Pulpwood, round and split	1
Industrial roundwood	1
Other industrial roundwood	1
Chips and particles	2.85 m^3/m^3 log
Wood residues	1
Sawn timber (m^3)	
Coniferous	2.21
Non-coniferous	2.56
Wood pulp (t)	
Mechanical wood pulp	2.5
Semi-chemical wood pulp	2.67
Chemical wood pulp	4.49
Dissolving wood pulp	5.65
Other fibre pulp	3.87
Wood-based panels (m^3)	
Veneer Sheets	1.8
Plywood	2.3
Particle Board	1.51
Hardboard	2.03
MDF	1.68
Fibreboard, compressed	1.72
Insulating Board	0.83
Paper and paperboard (t)	
Newsprint	2.87
Printing and writing paper	3.51
Household and sanitary paper	4.35
Wrapping and packaging paper and board	3.8
Paper and paperboard NES	3.29

9.4. Appendix 4

Appendix 4. Table presenting the codes used in the presented equations to indicate statistical significance of the predictors.

p-value	Significance code
<0.001	***
<0.01	**
<0.05	*
<0.1	.
>0.1	[blank]